IMPERIAL INSTITUTE

MONOGRAPHS ON MINERAL RESOURCES WITH SPECIAL REFERENCE TO THE BRITISH EMPIRE

PREPARED UNDER THE DIRECTION OF THE MINERAL RESOURCES COMMITTEE OF THE IMPERIAL INSTITUTE WITH THE ASSISTANCE OF THE SCIENTIFIC AND TECHNICAL STAFF

MERCURY ORES

BY

EDWARD HALSE, A.R.S.M., M.Inst.M.M.
SCIENTIFIC AND TECHNICAL DEPARTMENT, IMPERIAL INSTITUTE

WITH A MAP

LONDON
JOHN MURRAY, ALBEMARLE STREET, W.

FIRST PUBLISHED 1923

Printed in Great Britain by
Hazell, Watson & Viney, Ld., London and Aylesbury.

IMPERIAL INSTITUTE

MINERAL SECTION

THE Imperial Institute is a centre for the exhibition and investigation of minerals with a view to their commercial development and for the supply of information respecting the sources, composition and value of minerals of all kinds.

The Imperial Institute is provided with Research Laboratories for the investigation, analysis and assay of minerals, and undertakes reports on the composition and value of minerals, for the information of Governments and producing companies and firms, in communication with the principal users in the United Kingdom and elsewhere in the Empire.

Important minerals from within the Empire are exhibited in the respective Courts of the Public Exhibition Galleries, and also in the Mineral Reference Collections of the Institute.

A special staff is engaged in the collection, critical revision and arrangement of all important information respecting supplies of minerals especially within the Empire, new methods of usage and other commercial developments.

Articles on these and related subjects are periodically published in the *Bulletin of the Imperial Institute*, and monographs on special subjects are separately published under the direction of the Committee on Mineral Resources.

IMPERIAL INSTITUTE

Advisory Committee on Mineral Resources

*Admiral Sir Edmond J. W. Slade, K C.I.E., K.C.V.O. (nominated by the Admiralty), (*Vice-Chairman*).

Edmund G Davis, Esq.

*Professor C. H. Desch, D.Sc., Professor of Metallurgy, University of Sheffield.

*Wyndham R. Dunstan, Esq., C M.G , LL.D., F.R.S , Director of the Imperial Institute.

*Professor J. W Gregory, D.Sc., F.R.S., Professor of Geology, University of Glasgow, formerly Director of Geological Survey, Victoria, Australia.

Sir Robert Hadfield, Bart., F.R S., Past-President, Iron and Steel Institute.

Arthur Hutchinson, Esq., O.B.E., M.A., Ph.D., F.R.S., Department of Mineralogy, University of Cambridge.

W. W. Moyers, Esq. (Messrs. H. A. Watson & Co., Ltd.).

*J. F Ronca, Esq , O.B.E , A.R.C.Sc., Department of Industries and Manufactures (nominated by the Board of Trade).

R Allen, Esq., M.A., B.Sc., Imperial Institute (*Secretary*).

* Members of Editorial Sub-Committee.

MINERAL SECTION

Principal Members of Staff

Superintendent

R. Allen, M.A. (Cantab.), B.Sc. (Lond.), M.Inst.M.M.

Assistant Superintendent

S. J. Johnstone, B.Sc. (Lond.), A.I.C.

Assistants

W. O. R. Wynn, A.I.C. (*Special Assistant*)

G. E. Howling, B.Sc. (Lond.) (*Senior Assistant*)

F. H. Bell.

H. Bennett, B Sc. (Lond.).

A. T. Faircloth.

R.C. Groves, M.Sc. (Birm.), A.I.C.

E. Halse, A.R.S.M., M.Inst.M.M.

J. G. H. Johnston.

GENERAL PREFACE

THE Mineral Resources Committee of the Imperial Institute has arranged for the issue of this series of Monographs on Mineral Resources in amplification and extension of those which have appeared in the *Bulletin of the Imperial Institute* during the past fifteen years.

The Monographs are prepared either by members of the Scientific and Technical Staff of the Imperial Institute, or by external contributors, to whom have been available the statistical and other special information relating to mineral resources collected and arranged at the Imperial Institute.

The object of these Monographs is to give a general account of the occurrences and commercial utilisation of the more important minerals, particularly in the British Empire. No attempt has been made to give details of mining or metallurgical processes.

HARCOURT,
Chairman, Mineral Resources Committee.

IMPERIAL INSTITUTE, LONDON, S.W.7.
July 1920.

CONTENTS

found actually deposited in igneous rocks, they frequently occur in the neighbourhood of such rocks, and are doubtless genetically connected with them. The deposits are usually confined to zones of fracture and fissuring, and to the resulting breccias, sometimes forming wide lodes and even stockworks, moreover, they not infrequently occur in the neighbourhood of hot springs. As pointed out by Ransome [2/1917] and Spurr [3/p. 338], mercury ores, more commonly than with those of other metals, with the possible exception of antimony, are associated with volcanism as opposed to plutonic igneous activity, and were deposited comparatively near the surface. Hence mercury deposits as a rule are found in regions of Tertiary or later eruptions, which have not been subjected to long and deep erosion. There are, however, some notable exceptions to these generalizations. The great deposits of Almaden, Spain (depth 1,300 ft.), are found in Silurian and Devonian shales and quartzites with dolerite and melaphyre (altered olivine-basalt) intrusions. At Idria, in Carniola, Italy, the mercury deposits are found in Triassic rocks, although connected with Tertiary eruptives. The mercury deposits of Arizona, United States, are in pre-Cambrian schist, and are by no means clearly associated with volcanic activity. The deposits at New Almaden (2,200 ft. in depth) and New Idria, California, also have no obvious connection with volcanism.

Some of the scattered deposits of mercury, like those of the Adriatic region in Europe, have been shown by De Launay to belong to a single metallogenetic province, characterized by Tertiary eruptions. Similarly, as pointed out by Ransome, the somewhat scattered occurrences of mercury in the United States, Mexico, Peru and Chile coincide in part with the belt of Tertiary and Quaternary volcanic activity along the western sides of the continents of North and South America. On the other hand, the mercury deposits of Almaden (Spain), the Donetz Basin (Russia), Asia Minor and China appear to be isolated occurrences, that cannot at present be assigned to recognizable provinces of eruptive activity and metallization.

No mercury ore deposits are found in the United Kingdom, and such deposits as are known to exist in British Africa, Canada and Australasia are mostly too small, too remote or

too low in grade to work; nevertheless, small productions have been recorded from time to time, and it is quite possible that some of the deposits already discovered, explored and, to a certain extent, developed in Canada (*e.g.* Kamloops), Queensland (*e.g.* Kilkivan) and New Zealand (notably Puhipuhi) may eventually prove to be payable.

The great demand for, and the consequent increased price of, mercury during the war were owing to the large consumption of the metal in making explosive caps and detonators, but in normal times the uses for the metal do not call for large quantities, and the demand has hitherto been met from European and Californian sources, supplemented by comparatively small contributions from South America and China.

The world's production of mercury at the present time is about two-thirds of the normal pre-war amount. Consumption is even lower, owing to the general commercial depression and to the very small demand from Germany, formerly a large consumer.

Mercury-bearing Minerals

Mercury ores are few in number and of simple composition. The chief minerals are here described:

Cinnabar (HgS).—The only important ore of mercury. It is a bright red sulphide, usually occurring in a massive or granular condition, but crystals belonging to the rhombohedral system are sometimes found. It has a bright red streak and a sub-conchoidal fracture. Its hardness varies from 2 to 2·5 and its specific gravity from 8 to 8·2. Varieties are *hepatic cinnabar* and *coralline ore* (*see* p. 41).

Metacinnabar, usually known as metacinnabarite (HgS).—A black sulphide of mercury with the same chemical composition as cinnabar. Its habit of crystallization is tetrahedral (isometric system), but it is sometimes amorphous. In the crystalline form its hardness is 3 and specific gravity 7·81: its fracture is subconchoidal to uneven: it gives a black streak and possesses a metallic lustre. The amorphous variety has a somewhat lower specific gravity.

Calomel (Hg_2Cl_2).—This is mercurous chloride and is found

at Idria and at Almaden as one of the minor mercury minerals. It occurs in crystals, often highly complex, of the tetragonal system Lustre, adamantine, fracture, conchoidal; colour, white or yellowish-grey, streak, pale yellowish-white; hardness, 1 to 2, specific gravity, 6·5.

Native Mercury is somewhat rare. Small globules of it are sometimes found scattered in cinnabar, or through the rock or gangue material, at Almaden, Spain, at Idria, Carniola; at Monte Amiata, Italy, and at other localities where there are mercury deposits. It is of secondary origin.

Silver-amalgam, usually called amalgam (carrying various proportions of silver and mercury), has been found in certain silver mines in Chile, and is said to occur in the Palatinate, Germany, and in the Almaden mine, Spain, and elsewhere. It is also sometimes present in the silver ores of Cobalt, Ontario (*see* p. 26).

Mercurial fahlore or *tetrahedrite,* really a variety of copper ore, is sometimes a commercial source of mercury (*e.g.* in Bosnia, and in the Palatinate, Germany), but its occurrence may be regarded as rare.

Any of the above minerals may be tested for mercury by heating a portion in an open tube in the presence of lime or carbonate of soda. A sublimation of metallic mercury on the interior of the cooler part of the tube will be observed. In the case of the sulphides of mercury, these, when heated alone in a tube, give a sublimation of red sulphide and some metallic mercury, accompanied by a strong odour of sulphur dioxide [4].

Livingstonite ($2Sb_2S_3.HgS$).—A sulphide of antimony and mercury in steel-grey prismatic crystals, or columnar massive form, resembling stibnite. Lustre, metallic; streak, red; hardness, 2; specific gravity, 4·81. It is the primary mercury ore at Huitzuco, Guerrero, Mexico, where it has been mined for a long time. It has also been found at Guadalcazar, in San Luis Potosí, with gypsum, sulphur, etc.

Barcenite.—A complex secondary mineral, derived from livingstonite, and found only at Huitzuco. J. W. Mallet,

who in 1878 named the mineral after Mariano Barcena, the Mexican geologist, regarded it as a mixture of sulphide of mercury and the oxide of antimony (Sb_2O_3). It occurs massive, dark-grey or nearly black, with an ash-grey and slightly greenish streak. Hardness, 5·5 ; specific gravity, 5·343.

Guadalcazarite.—This mineral is of nearly the same composition as metacinnabar, but contains a little zinc (2 to 4%), and from a trace to over 1% selenium. It occurs massive, with cinnabar, barytes and quartz, at Guadalcazar, San Luis Potosí, Mexico.

The following oxychlorides of mercury may be regarded as rare minerals, but they occur in Brewster Co., Texas, in sufficient quantity to be mined, and both have been met with in a fractured zone in the Dulces Nombres mine, San Luis Potosí.

Terlinguaite (Hg_2ClO).—Occurs in very small sulphur-yellow crystals (isometric system). The colour darkens to olive green on exposure to air. Hardness, 2 to 3 ; specific gravity, 8·725.

Eglestonite (Hg_4Cl_2O).—Is found in tiny brownish-yellow crystals (monoclinic system) of a resinous lustre, which blacken rapidly on exposure to the sun. Hardness, 2 to 3 , specific gravity, 8·327 [5], [6], [7].

Kleinite, principally mercury-ammonium chloride occurs in sulphur-yellow crystals (hexagonal system) of an orange tinge where the gangue shows signs of decomposition. Hardness, 3 to 4 ; specific gravity, 7·98 [7], [8]. It is a secondary mineral and occurs with terlinguaite.

Mosesite, another mercury-ammonium chloride, also occurs with terlinguaite.

Montroydite (HgO).—Exists in orange-red acicular crystals (orthorhombic system), with vitreous lustre. Hardness, below 2. The mineral is found associated with the four minerals described above, in Brewster Co., Texas [5], [6].

Other rare mercury minerals are *tiemannite* ($HgSe$), *onofrite* [$Hg(S,Se)$], *coloradoite* ($HgTe$), *lehrbachite* (a selenide of lead and mercury), and *iodyrite*, a rare iodide of silver and mercury, found only in Chile.

GENESIS OF MERCURY ORES

It is generally agreed amongst geologists that cinnabar and other ores of mercury have been deposited from aqueous solution. Evidence in support of this conclusion is afforded by the nature of the associated gangue minerals, and by the fact that mercury minerals are found in the vicinity of hot springs, as at Sulphur Bank, California; Steamboat Springs, Nevada, and Ohacawai, New Zealand; or in regions which bear unmistakable signs of the former existence of such springs. The source of the mercury in solution in these waters is assumed to be the minute quantities contained in certain igneous rocks. It has been ascertained that most deep-seated underground waters, in addition to other dissolved substances, carry alkaline sulphides in solution. Cinnabar and other minerals commonly associated with it are soluble in such a solution forming a double salt with one of the alkalies, as, for instance, $HgS_4.Na_2S$; from this it may be precipitated as a sulphide with a little free mercury, by dilution, or by the action of some bituminous matter [9/p. 224].

Whatever the source of the underground waters from which mercury minerals are deposited, whether meteoric or magmatic, the opinion most strongly held is that the deposition of these minerals and of that of their associates is from waters ascending from a zone of moderately high temperature and pressure to other zones in which these become gradually lessened, the dissolved minerals under these conditions being deposited in the reverse order of their solubilities. The vertical distribution of mercury minerals in fissure veins supports this view, and the fact that mercury ores are chiefly confined to shallow depths is thus explained.

There has been some enrichment in mercury deposits, but far less than has been the case with such metals, for instance, as copper and silver. Broderick [10] has proved the ready solubility of cinnabar in chloride waters, and its insolubility in sulphate waters. Secondary minerals, as metacinnabar, cinnabar, native mercury, calomel, the oxychlorides and the oxide, do result from processes of sulphide enrichment, but they are small in amount for the reason that

chlorides in general are not abundant in waters of deposits of mercury ores. Mercury is placed by Emmons with non-migratory metals [11], but migration has possibly occurred in some instances (*see* pp. 42 and 63).

Mining of Mercury Ores

As mercury-ore deposits occur in a great variety of rocks and under many forms, a considerable variation in mining practice is observable. The fact that payable ores of mercury frequently contain only 1% or even less than 1% of metal demands considerable experience and judgment in laying out the mine workings. In some of the larger mines of California (*e.g.* New Idria and Oceanic) wide overhand stopes are common, square sets being used for the support. At the Oceanic Mine the deposit is worked away in horizontal slices by means of intermediate levels, 25 ft. apart, between two main levels, which are 150 ft. apart vertically, and which are well timbered. A rise is put up at the far end of the block, and the angle of stoping is such that the ore can fall freely to the lower level. A caving system has to be used in the same mine below certain old workings. Some sorting is done underground both in the New Idria and New Almaden mines, but this is exceptional in mercury mines.

The method of mining employed at the Almaden mine, Spain, is quite unique. It owes its origin to Diego Larranaga, and was definitely adopted in 1804. It may be described as a crosscut method with arching and masonry packing, which, as regards details, has been improved upon in recent years, bringing it more into line with modern practice.

The deposits consist of three wide parallel and nearly vertical cinnabar-bearing quartzite lodes, separated by country-rock (*see* p. 50). The ground is opened up as follows: At any given level a crosscut is driven from the shaft to the centre of the run of ore, and continued as a cross-drift until the centre of the lode farthest from the shaft is reached. Half-way between the two lodes nearest the shaft a main gangway is driven in the country-rock in a direction parallel with the lodes. From this gangway crosscuts are

driven, 130 ft. apart, and at the point where the crosscuts intersect the lode, winzes (*profundidades*) are sunk from the upper to the lower level, 82 ft. in vertical depth.

The actual exploitation is divided into three periods:

1st Period.—The central third of each lode is stoped away overhand from the winzes. The ore left standing (two-thirds in amount) is supported by stulls, provisional brick arches carrying masonry, or, in the poor portions of the lodes, by pillars or arches of ground.

2nd Period.—Cross-drifts, 11·5 ft. wide, are run from the central gallery in each lode to both walls, leaving 11·5 ft. of solid ground between each pair of cross-drifts. Across the open spaces brick arches (*fundamentales*) are built with mortar, 2¾ ft. in thickness, but variable as regards rise and span. The lower buttress or impost (*rafa*) rests on the foot-wall, and the upper one (*cabeceadero*) on the hanging-wall. When the distance between two lodes is small, they may be connected by a single arch, which may be from 60 to 65 ft. in span. The ground above the arches is stoped away overhand, the spaces being filled with masses of masonry (*obras*) of hard gritstone. These two periods are now worked almost simultaneously.

3rd Period.—The remaining third of the lode, left between the columns of masonry, and known as "reserves," was formerly left in the mine, but is now taken down by underhand stoping, the hanging-wall being well supported by timber or by brick arches [12], [13].

Needless to say the ore is high-grade (averaging 8% mercury), or such a costly method would never have been adopted.

De Kalb suggests, as an alternative, bulk-heading and filling portions of the mine with broken rock. He believes that this method would be sufficient, and would prove far more economical than the old method [14].

It is said that the Council which now administers the Almaden mine (*see* p. 16), in order to lessen the cost of supporting the workings, will adopt a new system of packing, and will effect other economies by increasing the number of rock-drills in use, and by electrifying all the services in connection with the mines and smelters [15].

The mining of mercury ore is reputed to affect adversely

the health of those engaged in it, more particularly when the ore contains native mercury, but with good ventilation, attention to cleanliness, and frequent changes from underground to open-air working, conditions which prevail at Idria in Carniola, it has been proved by statistics that there are no severe cases of mercury poisoning. The difficulty experienced is to induce the workmen to observe the regulations, and to use the facilities provided for the protection of their health. The neglect to do so makes it impossible to avoid completely mercurial poisoning in the mining and reduction of mercury ores.

A. J. Orenstein considers that the recommendation that workers be periodically interchanged is not based on a sound appreciation of all the factors involved, and that the bulk of mercurial poisoning can be prevented by the cleansing of their hands thoroughly after handling mercury. This is the first line of defence, and the second one, of course, is the carrying away by ventilation and by special devices (of which there are several) of the fumes from steaming plates and retorts [16].

Concentration of Mercury Ores

The fact that mercury ores are seldom found massive but more usually in the form of narrow veins, or as disseminations or impregnations in siliceous or limestone rocks, necessitates generally the mining of a large proportion of useless material. The result is that the average content of the ore sent to the reducing furnaces is seldom more than 1% mercury (*see* p. 10).

Mercury minerals, while of high specific gravity, tend to form a large proportion of slime when mechanically crushed, and this slime is only very partially recoverable by wet gravity methods of concentration. Until recent years concentration of mercury ores, preliminary to the furnace treatment, was restricted to the removal by hand-picking of the obviously barren fragments of gangue, leaving the whole of the remainder to go to the furnaces. In exceptional cases hand-picking could be employed in the selection of a rich smelting material for separating the coarser fragments of the best ore, which

would be separately distilled in retorts or other special furnaces. At the present time wet gravity methods are employed, especially with low-grade ores.

In California, extractions as high as 86% have been obtained by crushing, followed by concentrating on tables. The first successful modern concentrating plant was that of G. V Northey at the Manzarita mine, in Colusa Co The ore, first broken by a Gates crusher, was passed through a Huntingdon mill and over a series of bumping tables. The tailing from the tables was passed to cone classifiers, the overflow going to a belt vanner and the underflow to a Bartlett concentrator.

The new Idria practice is to crush in a ball mill, and then to pass the product through several Richards pulsator classifiers. From these the sand product passes over Overstrom concentrators, and the fine product goes direct to Deister slime tables. The concentrate is heated to 50° C. in a rotary drier before being fed into a Scott furnace.

At other mercury mines in California, Wilfley as well as Deister-Overstrom tables, and classifiers of the Dorr simplex type, have been used. Sometimes a jaw crusher precedes the ball-mill, and jigging is used ahead of concentration on tables. This has proved a success in some instances.

In the spring of 1917 a series of experiments with flotation was carried out at New Idria. The ore used assayed 14 lb. mercury per ton (0·7%). After table concentration, the tailing assayed 4 lb., but after table concentration and flotation combined it assayed 3 lb. per ton. However, it was found that "flotation alone did not give as good a result as the tables alone" [17/p. 342].

Metallurgy of Mercury

The ore-mineral to be treated is almost invariably cinnabar (HgS), the average content of the ore being usually from 0·5 to 1% mercury. The metal is recovered from the ore as a volatile vapour at comparatively low temperatures; therefore, in order to obtain a high percentage of extraction, both furnaces and condensers used must be highly efficient.

Three processes are used for the reduction of cinnabar:

(1) An air-reduction process; (2) reduction by lime (CaO), (3) reduction by metallic iron. The reactions are expressed by the following equations [18]

(1) $HgS + O_2 = Hg + SO_2$;
(2) $4HgS + 4CaO = 4Hg + CaSO_4 + 3CaS$;
(3) $HgS + Fe = Hg + FeS$.

(1) is the usual process, while (2) and (3) are only used for very rich ores.

In Europe and America shaft furnaces are used for coarse ore, and reverberatory furnaces of a special type for fine ore. The Czermak-Spirek shelf or tile furnace is designed for treating medium coarse and fine ore, and is largely used in Europe. It consists of four rectangular chambers built into one block. There are two main fire-places and two subsidiary ones, a channel connects the two former and acts as a combustion-chamber, the air, passing through cast iron tubes in the bottom of the furnace, is pre-heated by the hot spent ore Each chamber or shaft has from 4 to 8 rows of ridges of tiles so arranged that the ore charge gradually passes down from one to the other until it reaches the discharge opening The uppermost ridges are of cast iron, the remainder of fire-clay. The openings between the ridges are from 3 to $4\frac{3}{4}$ in. wide.

The output varies from 12 to 24 tons of ore in 24 hours. The fuel used may be wood, lignite or coal [18].

In 1918 a rotary furnace of the cement-kiln type was introduced at the New Idria mine, California, by H W. Gould, oil being used as fuel, but it does not appear to have proved satisfactory on certain classes of ore [19/1918, p. 638].

The Scott type of shelf furnace for coarse ore is largely used in California, on account of its simplicity. The Hüttner-Scott furnace, designed in 1875–6, has four rectangular chambers or shafts built in one block, with one or two fire-places. In each shaft are fixed from 8 to 16 series of flat tiles, the two upper of cast-iron and the remainder of fire-clay, so as to form a zigzag channel for the passage of the ore from the top to the bottom of the chamber. The tiles are placed at an angle of 45°, and the openings or shelf-slits vary from 5 to 8 in. in width [17/p. 231], [18].

The Czermak-Spirek reverberatory furnace for fine ores has a long bed and a series of parallel flues beneath it, through which the flame and gases from the fire-place pass before going over the hearth. The capacity is from 6½ to 7 tons of ore in 24 hours [18].

Retorts, when used for high-grade ores or material such as mercurial soot (*stupp*), are of cast iron, and are set in brickwork. A charge per 12 hours consists of 150 lb. of ore and an excess of lime (*see* p. 11). The mercury is condensed in a tube cooled by water.

The gaseous and other products of combustion issuing from the large furnaces may consist of mercury, steam, mercurial salts, sulphur dioxide, carbon dioxide, hydrocarbons, dust, fuel, ash and soot, so that a capacious condensing plant with a large cooling surface is essential. In Europe, a series of large stoneware tubes, followed by wooden or glass chambers, is used; whilst in America, a succession of brickwork chambers, sometimes followed by towers of wood and glass, is employed. In either system, an induced draught is necessary, which is created by the use of fans.

Czermak's condenser is typical of modern tubular forms and consists of a series of pairs of vertical tubes of cast iron, or glazed stoneware, of elliptical cross-section set in a line—there may be from 6 to 9 of these lines. Each pair of tubes is cemented into a V-shaped receiver, the lower end of which is open and dips to a depth of 2 in. in water contained in a tank, in which mercury and mercurial soot collect. The tubes are cooled by water. The cooled gases pass from the condenser to a large wooden condensing chamber divided by baffle-walls, in which they follow a zigzag course, being exhausted by a fan, and delivered to a chimney-stack. At the clean-up, which takes place every 5 or 10 days, the greater portion of the mercury is extracted mechanically from the mercurial soot, and the last portions are re-distilled [18].

Fume and other losses in condensing mercury from furnace gases have been investigated by Duschak and Schuette. Their experiments show "that there are no inherent difficulties that prevent the recovery of at least 96 to 99% of the mercury vapour entering the condenser system" [20].

Where wood fuel is scarce or prohibitive in price, electric ovens for the ore-reduction have been proposed [21].

In 1908–9 W B. Dennis conducted a series of experiments with a gas producer and a roasting furnace, specially designed by him for the attainment of steep temperature slopes. By these experiments a reduction of the roasting period of mercury sulphide ore from 24 and 36 hours (using pine and hemlock fuel respectively) to 4 hours (using a gas-producer) was effected, with a cleaner and in every way more satisfactory roast [22].

A wet process for treating cinnabar ores has been the subject of experiments by W. W. Bradley [17/pp. 321–8], but so far the process does not appear to have been commercially applied.

The average total cost of producing a flask of mercury in Europe is about £6 15s. at the present time [19/1921, p. 610].

Properties and Uses of Mercury

Mercury, as already mentioned in the Introduction, is the only metal which is liquid at ordinary temperatures. It has a silvery white colour and perfect metallic lustre, and in very thin layers transmits a bluish-violet light. It freezes at about 39° C., forming a tin-white ductile and malleable metal. When heated, it vaporizes at 360° C. The specific heat of mercury is 0·0333; its thermal conductivity is about two-thirds that of silver; its electrical conductivity is 1·6, if that of silver be taken as 100; and its specific gravity is 13·59.

Mercury is used for many purposes; these, in the following notes, are placed in the order of decreasing consumption or importance:

Mercury enters largely into the manufacture of drugs and chemicals. The British Pharmacopœia contains some 25 mercurial preparations, including corrosive sublimate (mercuric chloride) and calomel (mercurous chloride), which are therapeutically the two most important of all. Mercuric chloride and iodide are among the most powerful of all known antiseptics.

Fulminate of mercury is the detonating agent used for firing explosive charges in mines and quarries. During the

war it was used in detonators for small-arm ammunition, as well as for torpedoes, floating mines, high explosive shells and for the larger guns. Recently a large part of mercury fulminate in detonators for high explosives has been replaced by picric acid, trinitrotoluene, etc., and for certain uses it has been proposed to replace entirely mercury fulminate by lead azide, a salt of hydrazoic acid, and other substances [2/1919].

A large quantity of mercury is used in the manufacture of vermilion (mercuric sulphide), the well-known brilliant red pigment, and probably a similar quantity, in the form of red oxide of mercury, is utilized in paints for the bottoms of ships, as in sea-water it becomes chloridized, and in that condition is poisonous to barnacles and other marine organisms, and "saves many a trip to the dry dock" [23].

A fairly large quantity of mercury is consumed in electrical apparatus, including rectifiers for changing alternating into direct current, mercury-vapour lamps and storage batteries.

In the manufacture of felt hats from rabbits' fur, mercuric nitrate is used to roughen the hairs so that they will adhere together, a process technically known as "carroting" [2/1919].

Formerly a large quantity of mercury was used in the amalgamation of gold and silver ores. Briefly, the process depends upon the fact that when gold and silver in the free state, and silver in some of its compounds, are brought into contact with metallic mercury, solid amalgams are formed, from which the precious metals are recovered by distillation in a retort. The mercury, escaping as vapour, is condensed in a tube cooled by a stream of cold water, and the gold and silver are left behind as a spongy metallic mass. Of late years the amalgamation method has been largely replaced by the cyanide process, thereby effecting a large economy in the consumption of mercury.

Some mercury is used in the construction of instruments, such as barometers, thermometers, thermostats, gas governors, automatic sprinklers, etc.

Among the miscellaneous uses of mercury, the following may be mentioned: the silvering of mirrors, an old method, however, now very largely replaced by the silver nitrate process; the floating of certain types of revolving lights in

lighthouses and parts of some gyroscopic compasses; as a cathode in place of platinum in electro-analytical work, and in various electrolytic manufacturing processes, such as certain of the methods now in use for the production of caustic alkalis [24]; as an oxidizing agent in the manufacture of certain chemicals, such as glacial acetic acid; as mercurous nitrate and mercuric chloride in testing brass artillery cases and fuses, in dental amalgam; in cosmetics, and in certain compounds for preventing boiler scale.

According to a recent British patent, the addition of small quantities of mercury increases the hardness of certain lead alloys, and, in a recent German patent, mercury is substituted for tin in making stereo- and type-metal alloys. Experiments have been carried out on a considerable scale to determine the possible advantage of using mercury vapour with steam in turbino-generators. These experiments are still in progress [2/1919].

J. J. Haak and R. Sissingh have shown that a layer of absorbed gas, only one molecule thick, can be detected optically on the surface of mercury [25].

Prices of Mercury

The market unit for mercury by which it is quoted and sold is peculiar to itself, being the iron flask containing about 75 lb.[1] of the metal. The price of mercury is subject to considerable fluctuation, in this respect not differing from the prices of other economic base metals. Some approach to stability of prices has hitherto been attained by the control in the English market of the large production and marketing of the mercury from the Spanish mines, but, nevertheless, a comparison of the average yearly prices for the six years preceding the war shows a variation of about 20% between the highest and lowest prices for that period.

During the war there was an abnormal rise in the price of mercury, as it was needed for munition purposes. The average price from 1908 to 1914, inclusive, was about £8 6*s*. 4*d*.

[1] Prior to 1903 in Europe and to 1904 in the United States the iron flask contained about 76½ lb. At one time mercury was sold in sheepskin bags holding about 56 lb.

per flask The average London price per flask rose to £14 15*s.* in 1915, and reached as much as £20 10*s.* in 1918. Since 1918 the price has gradually fallen, but it has not yet dropped to the level of the prices ruling before the war.

The contract by which the Rothschilds had the exclusive rights, from about the middle of the last century, for the sale of the mercury produced in Almaden expired on December 31, 1921.

Since then the market position has been very obscure. Negotiations are taking place (1922) between Spain and Italy. Indications are that the market will leave London.

The mine for some time has been managed by an autonomous Council, appointed by the Government, which, by Royal Decree, is now free to fix the price of the metal [15]. The board of management are granted the fullest possible powers, including the right to enter into agreements with other quicksilver producers, with a view to fixing minimum prices for a period not exceeding six months—the authorization of the Government being required for longer periods. Mercury required for consumption in the national industries will be sold with a rebate, to be fixed by the board of management or Council. Similar powers are granted to the board with regard to the sale of the output of the Arrayanes mines [27]. Outside the English market for mercury, the principal market is the United States. The prices in America, while bearing a close relation to those of London, are appreciably higher. The following table giving the average yearly prices in England and New York for recent years shows this relationship :

Average Prices of Mercury per Flask of 75 lb.

Year.	New York (*a*)	London (*b*).	Year.	New York (*a*).	London (*b*).
	$	£ *s.* *d.*		$	£ *s.* *d.*
1911 . .	46·54	8 14 11	1917 . .	106·30	22 4 3
1912 . .	42·46	8 2 10	1918 . .	123·47	(*c*)
1913 . .	39·54	7 9 2	1919 . .	92·15	20 9 6
1914 . .	48 31	7 15 0	1920 . .	81·12	20 15 6
1915 . .	87·01	14 10 8	1921 . .	45·46	11 0 3
1916 . .	125·49	17 2 10	1922 . .	46 00	11 5 0

(*a*) *Eng. and Min. Journ.*; (*b*) *Min. Journ.*; (*c*) Quoted as "nominal" only.

The fact that, at normal prices, production is practically restricted to a few mines favoured either by comparatively large, or exceptionally rich, deposits of ore, and that elsewhere it is of an intermittent character, only reviving when prices are high, suggests that mercury mining is not ordinarily a particularly profitable branch of the mining industry.

The following tables give for recent years the world's production, the imports of mercury of the chief importing countries, and the exports from, and imports of mercury into, the United Kingdom :

World's Production of Mercury (a)

(In 100 lb.)

	1912	1913	1914.	1915	1916	1917.	1918.	1919	1920	1921.
Australia [1]	—	—	—	13	7	—	—	—	—	—
New Zealand [2]	—	—	—	—	—	41	113	112	113	
Austria	16,813	18,078	19,405	16,755	9,048	14,300	9,260	*	*	
Hungary	1,871	1,958	1,660	1,396	1,764	2,086	1,764	†	†	
Italy	22,051	22,135	23,656	21,716	24,105	23,620	22,884	18,629	29,203 [3]	24,244 [6]
Russia	—	—	—	600	825	375	—	—	—	—
Spain	27,691	27,464	21,000	26,944	17,525	18,860	12,508	27,041	19,900	13,244 [6]
China [4]	95	46	1,315	4,645	3,919	5,760	6,468	1,772	933	
Mexico	3,643	3,654	3,580	2,072	1,157	730	3,507	2,622	1,697	2,204 [6]
United States	18,798	15,160	12,411	15,775	22,449	27,119	24,662	16,061	10,044	4,754 [5]
Other Countries	10	409	21	27	776	479	320	212	337	2,204 [6] ‡

(a) "Quicksilver in 1920," *Min. Res U S. Geol. Survey.*
[1] *Ann. Rept. Dept. Mines, New South Wales* (Annual).
[2] *Mines Statement, New Zealand* (Annual).
[3] *U.S. Comm. Rept.*, No. 59, March 14, 1921.
[4] *Trade Returns, China*, Exports.
[5] *Min and Sci Press*, Feb 11, 1922, p. 196
[6] *Metallgesellschaft*, 1922
* Producing mines now owned by Italy.
† Producing mines now owned by Czechoslovakia
‡ Asia

Imports of Mercury into the United Kingdom [1]

(In 100 lb.)

From	1912	1913.	1914.	1915	1916	1917	1918	1919	1920	1921
Spain . . .	26,711	26,625	23,198	21,590	23,328	3,993	7,728	24,818	10,443	
Italy . . .	5,951	4,817	3,726	7,611	—	8,809	3,043	3,370	12 081	
Austria and Hungary	—	1,325	—	—	—	—	—	—	1,983	
France . . .	—	—	—	2	—	7,708	—	2	707	
Mexico . .	1,305	671	544	15	8	—	—	63	39	
Other Foreign Countries . . .	1,480	1,899	858	944	2,215	1,224	4	166	1,567	
British Possessions .	—	—	—	272	12	—	—	—	—	
Total . . .	35,447	34,012	28,326	30,434	25,563	21,734	10,775	28,419	26,820	15,406

[1] *Ann. Stat. Trade of United Kingdom,* vol ii

Exports of Mercury from the United Kingdom (Foreign and Colonial Merchandise) [1]

(In 100 lb)

To	1912	1913.	1914	1915.	1916	1917	1918	1919	1920	1921
India	2,868	1,994	1,208	780	2,575	659	238	5,395	1,033	
Hong Kong	7,796	6,275	1,357	637	263	—	—	9,106	4,673	
Union of S Africa	1,078	1,364	1,219	1,201	2,108	765	2,216	966	1,835	
Canada	861	539	1,378	665	735	52	133	64	—	
Australia	780	698	469	728	448	190	314	282	463	
Belgium	931	688	587	—	—	—	—	1,067	602	
France	1,548	1,497	3,319	2,277	2,768	728	1,171	1,444	506	
Germany	3,125	1,361	1,004	—	—	—	—	98	799	
Russia	2,101	2,445	1,286	1,098	1,182	1,149	—	59	98	
Japan	1,005	240	104	862	2,044	38	3,718	8,430	1,101	
United States	371	1,545	3,794	585	2,176	—	1	5,820	1,815	
Other British Possessions	276	335	340	184	265	218	268	68	795	
Other Foreign Countries	1,441	1,130	1,166	748	684	543	352	1,585	802	
Total	24,181	20,111	17,231	9,765	15,248	4,342	8,411	34,384	14,522	12,735

[1] *Ann Stat Trade of United Kingdom*, vol 11

Chief Importing Countries and their Imports

(In 100 lb.)

	1912.	1913.	1914.	1915	1916.	1917	1918.	1919.	1920	1921
United Kingdom[1]	35,447	34,012	28,326	30,434	25,563	21,734	10,775	28,419	26,820	16,406
India[2]	—	2,917	1,416	770	2,199	1,583	959	4,809	2,029	1,571
Union of S. Africa[3]	2,816	2,654	3,008	2,854	1,841	1,423	2,455	1,064	1,880	1,830
Canada[4]	1,375	2,194	2,042	1,844	792	716	569	265	2,090	346
Australia[5]	1,164	1,015	460	529	751	362	710	265	520	522
France[8]	4,695	4,357	3,689	7,267	12,520	10,800	18,773	4,137	4,628	705
Germany[6]	21,820	21,180	—	—	—	—	—	—	—	—
Italy[8]	33	7	nil	95	926	nil	nil	nil	nil	—
Sweden[6]	113	113	128	302	351	366	—	—	—	98
China[7]	1,080	882	511	264	481	319	156	795	775	990
Japan[8]	—	—	—	2,710	5,622	3,830	5,555	9,834	—	—
United States[9]	827	1,717	6,149	4,219	4,244	3,905	5,039	7,976	10,727	7,950

1 *Ann. Stat. Trade of United Kingdom*, vol. 1.
2 *Rec Geol. Survey, India* (Annual).
3 *Trade and Shipping, Union of South Africa.*
4 *Ann. Rept. Min. Prod, Canada.*
5 *Trade, Customs and Excise Revenue of Commonwealth of Australia*, 1915–20. Fiscal years ending June 30.
6 *Mineral Industry* (Annual)
7 *Trade Returns, China*
8 *Imp Min. Res Bur. Stat Summ.*, 1913–20
9 *Min. Res U S. Geol Survey*

CHAPTER II

SOURCES OF SUPPLY OF MERCURY ORES

(*a*) BRITISH EMPIRE

ASIA

British Borneo

In Sarawak cinnabar occurs in auriferous alluvial deposits (placers); in detritus; and, near Tegora and Gading, in clay-phyllites, alternating with sandstones, faulted, and altered into laterite. The sandstones are silicified, but the phyllites are decomposed to a clay, which contains fragments of black slate and of quartz. These beds are probably of Devonian age, and are overlaid by a Tertiary sandstone system of great thickness. The cinnabar deposits may be regarded as impregnations. The mineral occurs in threads, up to 6 in. in thickness, in patches and nests, or as films on the joint-planes, often accompanied by marcasite and barytes. At Gading the cinnabar has a crystalline structure, is associated with much pyrite, and there is more quartz in the veinstone than in that of the cinnabar at Tegora Stibnite is also said to occur with the cinnabar at Gading [28/p. 449] Both native mercury and calomel have been found in Sarawak, but they are rare.

From a few deficient data, which include mercury from alluvial and detrital deposits, the yield of British Borneo from 1868 to 1886, inclusive, appears to have been about 13,620 flasks, an average of 716 flasks per annum [29]. No records appear to have been kept since 1886.

India

Hitherto no undoubted occurrence of mercury or its ores has been recorded in any part of the Indian Empire.

Recently, however, cinnabar was detected in the sand of the Chitral River (N.W. Himalaya). A careful search has been instituted to locate the deposit [137]

AFRICA

Nyasaland

The presence of mercury ore has been reported in Nyasaland, but no details have been published [30/No 95, p. 63].

Union of South Africa

In the Transvaal cinnabar has been found in quartzites and altered slates in the Kaap Valley. To the east of De Kaap it occurs in a quartzose sandstone in the Lebombo Mts., and at one mine in the Marico district cinnabar is associated with galena and blende [31/p 484].

J. P. Johnson, on the authority of David Draper, states [32] that on the south of Madelane station, on the Pretoria-Delagoa Bay Railway, and on the further side of the range of hills between the railway and Louw's Creek, which it overlooks, cinnabar occurs disseminated throughout a belt of crushed quartzite, from 4 to 5 ft. wide, and about 400 ft. long. The mercury content over this width and length is from 2 to 3%. Numerous prospecting shafts have been put down on the deposit, but it appears to be of a superficial nature, for an adit driven lower down the hill failed to locate it.

Cinnabar has been reported to occur at Mosita, about 50 miles S.W. of Mafeking, in Bechuanaland, and native mercury is said to be associated with gold in the Prince Albert district of Cape Province [31]

NORTH AMERICA

Canada

British Columbia.—The only known region in Canada that may possibly contain mercury in commercial quantities is near Kamloops Lake, British Columbia. The cinnabar-bearing zone is 30 miles in length and 2 miles in width, with a N.-S. trend, but isolated occurrences of the metal are known 8 miles

both east and west of this belt The ages of the various sedimentary rocks range from Tertiary to Triassic. The region is geologically much disturbed ; there has been considerable faulting, owing to volcanic action, and it is a difficult matter to arrange the different dykes, beds of ash and sedimentary deposits which occur, in their proper order. There are four known beds of dolomite, which are separated from each other by intrusive or other rocks. Cinnabar is found in all the dolomite beds, but never far from porphyry beds, as well as in veins of dolomite cutting through decomposed volcanic rocks, in volcanic ash and conglomerate, and, at one point, in granite The cinnabar is contained in quartz veins, and is associated with stibnite. Bornite and hæmatite are occasionally found. The No. 3 dolomite bed is the one which has been principally worked. It is about 300 ft. thick, and has intercalated with it some black shales and grey argillites resembling arkose. It is overlaid by sheets of basalt and porphyry and some conglomerate [33].

The intrusive dykes found near the deposits have been described as older dark-green basalt or augite-porphyrite or augite-picrite by J. D. Kendall [33/p. 470], and as newer andesite or bostonite by others. The newer dykes have been shattered, and have been traversed by veins and masses of dolomite carrying cinnabar [34].

In one instance, where the ore occurs in a decomposed felspathic rock near the contact with an altered augite-picrite dyke in irregular layers more or less parallel to the contact (striking N.–S. and dipping W. 75°), it is associated with calcite, and, when examined under the microscope, the contact of the calcite and volcanic rock is seen to be ragged, which is suggestive of replacement (Kendall). It appears that the deposition of the cinnabar was due to the heat generated by volcanic action, at a period subsequent to the deposition of the dolomite. In many cases the fissures of the old thermal springs may be seen, notably at Hardie Mts. [33].

Some cinnabar mines, on the north side of Kamloops Lake, were owned and worked from 1895 to 1897 by the Cinnabar Mining Co., Ltd., of British Columbia [35], and about 150 tons of ore yielded 114 flasks of mercury. On

attempting to treat the lower-grade ore, the results were not financially satisfactory, and the works were closed down in 1897, since when they have not been reopened. The country is described as a grey felspathic and dolomitic rock. It is an altered greenstone, containing pyroxene and olivine [36].

The Hardie Mountain Cinnabar Mines, Ltd., have carried on some development work on other deposits about 10 miles north of Kamloops Lake A body of ore was exposed for a length of 1,000 ft. The ore, as formerly mined, carried about 0·75% mercury [37/1908].

At the Toonkwa Claim, 12 miles south of Kamloops Lake, cinnabar is found in the dolomite, sometimes in rich streaks, but generally disseminated in a zone several feet wide. Cinnabar, mostly in small quantities, has been found in many other places in the district, but outside the main mercury-bearing zone, and it is stated that there is an area of not less than 10 sq. miles in which prospecting might reveal important deposits

Cinnabar has been found in a massive limestone on the north side of the valley between Emerald Creek and Amiskivi River, and in the lower Kicking Horse Canyon in a calcite vein near Glenogle Station.

According to Victor Dolmage [38], there is a cinnabar deposit in a small creek of the Sechart Channel, Barclay Sound, Vancouver Island. Geologically it is in a small remnant of the Nitinat formation, included in the Beale diorite, near its contact with the Saanich grano-diorite. The inclusion consists of limestone interbedded with andesite, tuff and breccia, all intensely altered. The andesite consists largely of quartz, chlorite, pyrite, hæmatite and some aplite. Calcite, found plentifully in stringers, is of much more recent formation, and, later still were deposited, cinnabar, which is plentifully disseminated in places, native mercury and limonite. The limestone has been altered to a mixture of quartz and amorphous silica, and contains less cinnabar than the andesite. The breccia consists of fragments of quartz and limestone—for which cinnabar shows a marked preference, particularly the former—embedded in altered volcanic rock containing pyrite and, in rare instances, chalcopyrite. The diorites are pale-green

in colour, and consist of calcite, chlorite, kaolin, actinolite and quartz. There are numerous calcite veins in the diorite, and with them are associated cinnabar, serpentine and pyrite. Elsewhere along the contact the highly altered diorites contain tremolite, garnet, actinolite, hornblende, epidote, pyrite, chalcopyrite and large bodies of magnetite. These earlier minerals appear to have been replaced in the mercury deposit by quartz, amorphous silica and calcite. Pyrite was probably formed by the same solution that deposited the cinnabar, but the chalcopyrite is of earlier origin.

The rocks in which the mercury occurs are of Triassic and Jurassic ages, but, 50 miles away, in the southern portion of Vancouver Island there exists a large belt of basalts and gabbros of late Tertiary age and, about the same distance to the N W., a hot spring emerges from the Saanich granodiorite formation , hence the deposit is probably due to late Tertiary igneous activity, and the cinnabar may have been deposited by a hot spring. A sample from a large dump of mercury ore assayed 0·38% mercury. Victor Dolmage thinks it possible that thorough prospecting might disclose a profitable deposit of mercury in the vicinity.

Ontario.—Important deposits of mercury are said to occur at Groundhog, east of Cockrane, in Northern Ontario, but so far no development of these has been recorded. It may be mentioned as a mineralogical curiosity, that, in 1910, G. H. Clevenger found mercury in the silver ores of Cobalt, Ontario. Thirty-seven samples, chiefly from the Nipissing mine, yielded from a trace to 4·74% mercury, the average being a little under 1%. According to Clevenger, " the evidence available seems to justify the conclusion that mercury occurs as an amalgam rather irregularly distributed in the metallic portion of Cobalt ores, with a tendency for dyscrasite to carry a higher percentage of mercury than the purer forms of silver " [39].

AUSTRALASIA

AUSTRALIA

New South Wales.—There are a few deposits of mercury ore in New South Wales, and a small production of an inter-

mittent character has taken place in the past. Under present conditions production is suspended, apparently owing to the deposits being too low in grade to work.

On a flat near the Cudgegong River, Co. Roxburgh, is a deposit containing cinnabar from which a small output was formerly obtained, retorts and a condensing chamber having been erected. The deposit is a patch of Tertiary drift composed of water-worn quartz pebbles and ferruginous sandy clay, with irregular masses of brown ironstone overlying Devonian rocks. Two shafts, one about 200 ft. deep, and the other about 70 ft. deep, have been sunk on this deposit, however, there is little cinnabar below 40 to 50 ft. in depth. The ore is found in solid angular pieces up to several pounds in weight, and also as finely divided particles. Specimens examined by Carne [40] bore undoubted evidence of vein or fissure deposition, degradation and transport. The deposit proved to be an unpayable one For a number of years cinnabar was found in alluvial gold-workings at Spring Creek, near Bingara ; and in 1890 the mineral was found disseminated through serpentine, resulting from the alteration of an ultra-basic dyke intrusive into beds of claystone and limestone, probably of Siluro-Devonian age, which show distinct metamorphism. The cinnabar occurs disseminated in the dyke mass along its line of contact with the sediments. Some prospecting work has been done on this deposit, but no production has been recorded.

In the Upper Clarence district a deposit of cinnabar, in spots and stringers, occurs in a dyke, 12 ft. wide, of felspathic rock allied to serpentine. This dyke is about 3½ miles S.E. from Lionsville, and intersects the granite of the district.

In the same locality a discovery was made in 1895 of a cinnabar deposit at Yulgilbar Station, Clarence River. The country rock in which this deposit occurs consists of hornblende-granite and quartz-diorite. The sedimentary rock of the district is altered slate, which has been considered as belonging to the Devonian formation The ore occurs in veins and impregnations in three or more parallel bands of altered igneous rock in part replaced by calcite, and is believed to be of secondary origin.

The presence of mercury minerals in igneous rocks, which are not associated with sedimentary strata, is a special feature of the Yulgilbar deposits, as most important mercury ore occurrences elsewhere are related to the contact of sedimentary strata with intrusive igneous rocks. Rich specimens of ore have been taken from this deposit, but the average grade is quite moderate [40]. Much prospecting and development work have been carried on, and there was a small production in 1903, amounting to about 1,000 lb. of mercury.

At Pulganbar, Co. Drake, 12 miles from Copmanhurst, on the Clarence River, the geological formations consist of altered sedimentary rocks (age unascertained) with intrusions of grano-diorite and tourmaline-granite. One siliceous copper and mercury lode here strikes N. 20° E., and dips N 70° W. at 60° in tourmaline-granite Copper, although the principal constituent of this lode, has not been recovered, but the lode is locally estimated to yield 2% mercury. Another lode strikes N. 70° E. and dips N. 20° W. at 75° in grano-diorite, to a depth of 53 ft. From this depth to 147 ft. (the lowest level) the dip is 65°.

The bottom level, examined by Carne in 1911, showed an ore-channel from 3 to 18 in. in thickness, consisting of chalcopyrite, pyrite, cinnabar and calcite in hard quartzose rock. Very rich cinnabar was found in two lenses having a width of 2 to 8 in. The first lens of good ore is said to have had a width of 9 in. at 40 ft., and of 18 in. at 70 ft. A second lens of 18 in. was found at 105 ft. Between the lenses and below 105 ft. the lode proved to be very poor. An experimental retorting plant was erected here, and to the end of 1916 the production amounted to about 3,000 lb. of mercury.

Cinnabar also occurs in quartz veins in Pretty Gully, Co. Buller, at Corinda Creek, near Woolgoolga, Co. Fitzroy, and in a few other localities of New South Wales [40].

Queensland.—The mercury-bearing zone lies in Eastern Queensland, to the west of Kilkivan, between the heads of Wide Bay Creek and Kilkivan. Deposits of ore are somewhat numerous, and some of them are of fairly good grade. A few have been worked spasmodically, but indifferent transport facilities, the absence of efficient plant, and other causes have

checked production, which down to 1892 amounted to about 13,700 lb. of mercury.

One deposit, about 6 miles from the head of Wide Bay Creek, is described as of brownish quartz, the central portion being a conglomerate of quartz fragments cemented by deposition of silica from percolating waters. The ore mineral—cinnabar—occurs in micaceous and chloritic schists, and is disseminated through quartz, giving it a pinkish colour. The Wolf lode, which is about one foot thick, is composed chiefly of calcite, in which cinnabar occurs in bunches and also disseminated. The country consists of conglomerate, sandstones and shales [41]. Work of an exploratory character has been carried out. The depth of one shaft on the lode was 240 ft. [42].

A lode containing mercury ore occurs 1½ miles east of Messengers on King Bombi Creek in altered sandstone and greywacke. The gangue is calcite in the middle of a breccia of quartz and calcite, cinnabar and some free gold being visible in the calcite Another lode near by consists of a hard, brown jasperoid quartz stained with carbonates of copper, through which cinnabar is disseminated.

The Queensland lode is one of the largest and richest deposits in the state, varying in width up to 7 ft. in places; the ore, when dressed, gave 4 to 5% mercury. The ore is cinnabar in a quartz and calcite gangue, and the country is altered conglomerate, or agglomerate, probably of volcanic origin, being full of angular particles. Another cinnabar-bearing lode is found in a coarse-grained granite surrounded by a much-altered porphyritic rock—according to Ball, an andesitic lava [43]. A moderate production has taken place from this deposit.

Another deposit has been reported at Little River, near Cooktown, in Northern Queensland, in altered andesite. The alteration of the andesite has produced numerous thin veins of calcite, but very little quartz; and the cinnabar is found almost exclusively in cavities and on joints in the calcite. A little chalcocite was observed in the calcite, but no native copper could be found [43]. A trial lot of 1 ton of picked ore is said to have contained 5 to 6% mercury. According to

the Government analyst, ferruginous andesite containing specks of cinnabar gave 0·3 and 0·14% mercury and 0·3 and 0·2% copper on two samples respectively [43], [44/p. 624].

South Australia.—An occurrence of native mercury was reported some years ago from Myponga, 7 miles east of Willunga, South Australia. The country consists of clay-slate, graphitic slate, phyllite, mica-schist and quartzite, overlaid by comparatively recent detrital deposits with much white quartz and nodules of ironstone The country is auriferous, but no well-defined lode or body of ore occurs in the beds traversed by the galleries in which the mercury was seen. The mercury is found in small globules on surfaces, which had been exposed sometime to the atmosphere, but is not visible on freshly broken surfaces. No cinnabar or other mineral of mercury is associated with the mercury globules, so that their origin cannot be satisfactorily explained. Attempts have been made to explore the area by driving and sinking, but hitherto no deposit of value has been discovered [40]

Victoria.—Native mercury and cinnabar occur in dark Silurian slaty rock near Silver Creek, a western tributary of the Jamieson River, Victoria The mercury occurs in bands in the rock, extending over a width of about 10 ft., principally in or near small stringers of quartz. There was a small production in 1899, but the deposit has since been proved to be of no value [40]

Fragments of cinnabar have been found in the vicinity of a quartz reef near Bullumwaal in Central Gippsland [31/p. 486].

PAPUA

Mercury ore deposits have been found in Papua in four widely separated parts of the Territory: on the Mambare River, in the vicinity of Mt. Scratchley, at Merani, in Cloudy Bay; on Normanby Island, and on the Brown River [40/p. 49]. None of these has been explored to test its value.

NEW ZEALAND

Mercury deposits in New Zealand appear to be principally confined to the northern part of the North Island, from a few

miles north of Whangarei to the Bay of Islands. The most promising deposits are those of the Puhipuhi district, from 20 to 30 miles north of Whangarei, which follow a N.–S. line of faulting in sedimentaries (greywacke and graphitic schists) with later intrusions of basalt [135].

The Puhipuhi mine is being worked by the New Zealand Quicksilver Mines, Ltd In a recently published report [45] the lode is described as a fairly thick band of quartzose rock, apparently a silicified breccia, with a flat dip Black [135] describes the deposit as a cone or overlapping cones of chalcedonic quartz, typical of hot spring action, with sides dipping from 7° to 10°, the cone or cones have later been shattered, and then impregnated with cinnabar The cinnabar-bearing breccia, 2 to 6 ft. in thickness, was subsequently buried under basalt. It is estimated that there are at least 60,000 tons of ore now opened up, averaging over 1% mercury. The coarse material is treated in a Novak furnace. The fines, consisting of rich ochreous material, have not been utilized as yet.

The Rising Sun mine, 3 miles to the east of the last, is undeveloped, but possesses a furnace of the same type as the Puhipuhi mine.

The Mt. Mitchell mine is at the southern end of the faulted area. Black describes the deposit as a blanket of chalcedonic quartz on greywacke. Along the north and south line of faulting cinnabar has been deposited contemporaneously with the quartz, and has so far been proved to be 20 to 30 ft. thick. Boulders of quartz assay 2·5 to 5% mercury. Hepatic cinnabar and livingstonite have been discovered outside the main shoot.

About one million tons of ore, without overburden, are believed to exist here. An experimental reduction plant is being erected.

From 1917 to 1920, inclusive, about 500 flasks, or 17 tons, of mercury had been produced from the Puhipuhi deposits, and represent the total output of New Zealand for that period (*see* table, p. 18). The Mines Department is assisting the company to test the lode on its property by boring, and it is expected that this branch of the mining industry will show a considerable improvement in the near future [50].

In the Kauaeranga Valley, Thames Subdivision, Hauraki, Auckland, cinnabar occurs associated with bands of siliceous sinter, and occasionally with the more siliceous and brecciated portions of the altered andesites which enclose these bands. A small quantity—under one ton—of ore has been raised from a band dipping S. 10° E., and from 1 to 10 in. in thickness, carrying a few thin lenses of cinnabar. These lenses occur at or near the intersection of irregular highly inclined clay-filled fractures The mercury ore has been deposited by hot springs, and appears to be contemporaneous with that of the compact siliceous sinter. Some of the ore was rich, but the quantity was small [46]

Griffiths states [47] that he found small quantities of cinnabar as a pulverulent deposit lining the inside of cracks and small crevices of the quartz along the outcrop of the big Tui (auriferous) lode at Te Aroha, Thames Subdivision, and coating fragments and crystals of galena, blende and chalcopyrite from the galena lode on the foot-wall side of the Tui lode.

The Ascot Cinnabar mine at Mackaytown, Waihi-Tairua Subdivision, Hauraki, Auckland, has been opened on a very similar deposit Here two sinter-beds, dipping N. 10° to 15°, the upper being 10 ft. and the lower 20 ft. thick, are separated by a band of rusty or whitish kaolinized andesite, which in places contains much sinter. This band represents the principal ore-bearing horizon. The sinter is usually dense and jasperoid, but in places is pitted and honeycombed, some of the cavities being lined with drusy quartz. A banded structure is not uncommon. The sinter is generally dark-coloured, and sometimes highly pyritic. Cinnabar occurs associated with fractures, ramifying veinlets and geodes in the sinter and in the silicified andesite. It is in many places accompanied by whitish flinty quartz. In the neighbourhood of fractures the cinnabar sometimes impregnates the solid sinter. Just above the 20 ft. bed there is a somewhat persistent fracture of the same dip as the bedded complex. This fracture or vein usually contains drusy quartz, cinnabar and much yellow clayey material, varying from a mere seam to 4 ft. in thickness. The lenticular seams in it are filled with clay and carry cinnabar. The cinnabar has evidently been deposited by hot

springs, and the metal-bearing solution, which was the carrier, is of later origin than the waters which deposited the mass of the sinter [48].

The Ascot mine was developed to a certain extent a few years ago, and some ore was raised and treated in a Novak furnace, which had been installed, but on the whole the cinnabar at Mackaytown proved to be of sporadic occurrence, and there has been no regular output [40], [48].

In 1899 the discovery of a cinnabar vein in the Waitahuna Ranges, Province of Otago, South Island, was reported. Rolled fragments of cinnabar were traced to a lode 16 in wide, in which about 3 in. of cinnabar occurred on the hanging-wall [40].

Marshall [49] states that the cinnabar occurs in a schist lode formation, 4 ft. wide, which strikes about N.–S. and dips E. 28°. The enclosing rock is partly metamorphic sandstone, often crushed, and having a strike of about N.E. and dip S.E. 12°.

An interesting deposit of mercury ore is that at the Ohaeawai Hot Springs in the Bay of Islands Co., north of Auckland. According to André P. Griffiths [47] the country around the Tuwhakino and Ngawha Hot Springs consists of undulating hills mainly composed of fine blue limestone and fireclays, which are covered by layers of varying thicknesses of "green sand," marly clays and flints, composing nearly the whole of the Tertiary coal measures of the island. These undulating hills form several crateriform hollows of varied diameter and depth, in which are found the hot springs and mercury deposits. The deposits formed by the springs consist essentially of beds of moderately hard, brown and grey sandstone, or solidified siliceous mud, with layers of calcareous and siliceous sinter, through which the cinnabar has been deposited, together with native sulphur. They include also several layers of bituminous shale, containing an appreciable quantity of petroleum oil. There are, moreover, deposits of pyrite, with or without cinnabar, in some cases containing traces of gold and silver.

The cinnabar of Ohaeawai is associated in places with calcite, chalcedonic quartz, marcasite, sulphur and bituminous matter,

but it usually occurs alone, lining small cavities and cracks in the solidified muds and green sand immediately surrounding the original fissures of the underlying basalt, and also impregnating a fragmentary sinter overlying the fine muds or sandstone, but below the bituminous shale. The cinnabar is found in a very pulverulent state in cracks in the muds. These cracks are very numerous, but small, and the cinnabar cannot therefore be mined without including a large proportion of useless material. Pure cinnabar is frequently found coating the roots of trees which formerly grew on the spot, and of which remains exist in the shape of charred logs partially or entirely embedded in the mud and sands. At one point only were pyrite and cinnabar found together, and in this case the lode consisted of small crystals of pyrite cemented together by cinnabar, and the deposit was characterized by a strong evolution of hot sulphurous gases, the heat of the ground rapidly increasing with depth. Samples of ore from this particular deposit assayed from 8 to 22% mercury, but were probably not typical ones.

The Tuwhakino Hot Spring is depositing cinnabar within the crater of a moribund volcano in the last stages of solfataric activity. The watershed formed by the margin of the crater collects the rainfall and surface drainage into a pool at the bottom, about 60 ft. in diameter. Hitherto all attempts to mine round the pool beyond a depth of 10 or 15 ft. were baffled by the sodden ground and heated waters, and by fumes of sulphuretted hydrogen, sulphurous and carbonic acid gases. S. L. Bensusan believed that the Tuwhakino Hot Spring deposit could be drained and worked Samples, so far as obtainable under the circumstances, contained from ½ to 6% mercury.

CHAPTER III

SOURCES OF SUPPLY OF MERCURY ORES (*continued*)

(*b*) FOREIGN COUNTRIES

EUROPE

As already pointed out (p. 2), the mercury deposits of the Adriatic region of Europe are regarded as belonging to a single metallogenetic province, characterized by Tertiary eruptives. This region comprises Idria and Monte Amiata, in Italy, and Avala, in Serbia (Yugo-Slavia). On the other hand the deposits of Almaden, Spain, and the Donetz basin, Russia, appear to be isolated occurrences. The deposits of mercurial tetrahedrite in Czechoslovakia, Bosnia (Yugo-Slavia) and Northern Hungary appear to belong to a distinct class of mercury occurrences, and are so regarded by Beyschlag, Vogt and Krusch [26], but it must be admitted that in the Palatinate, Germany, mercurial tetrahedrite, in at least one locality, is associated with cinnabar, the latter mineral being by far the more abundant. Mercurial tetrahedrite and cinnabar are also associated at Punitaqui, Chile. The two minerals also occur together in Northern Hungary and in Czechoslovakia, but in these instances the cinnabar is quite subordinate and secondary, being found only in the oxidation zone.

From an economic point of view the deposits of mercurial tetrahedrite are unimportant.

ALBANIA

It has been reported that deposits of cinnabar and native mercury exist in Albania, but details are not known [30/No. 17, p. 88].

Czechoslovakia

Bedded siderite lodes, containing mercurial tetrahedrite, are found in slates of Devonian age near Iglo, in the Western Carpathian Mts. Cinnabar, accompanied by native amalgam, pyrite, quartz and barytes occurs in the oxidation zone. Below the latter, tetrahedrite, containing up to 16·7% mercury, is found The tetrahedrite is roasted, the mercury being recovered as a by-product. The deposits near Iglo formerly belonged to Hungary

In the Thihu Valley, also in the Carpathians, veins and nests of cinnabar, galena and blende occur in a zone between a lava sheet and a much-altered clay-slate.

The iron deposits of Horowitz in Bohemia contain small amounts of cinnabar, native mercury and calomel [26/p. 482]

France and Corsica

At Méníldot, department of Manche, France, cinnabar is found in Palæozoic schists, with pyrite and quartz. Near Grenoble, department of Isère, cinnabar, according to Kuss, is disseminated in dolomitic limestones (Liassic), associated with blende, calamine, tetrahedrite and galena, the gangue being calcite From 1850 to 1854 some unsuccessful attempts were made to work the deposit. At Chalanches, in the same department, cinnabar together with some native mercury and native amalgam, occur in blende-galena veins traversing crystalline schists containing traces of platinum.

In Corsica cinnabar is associated with stibnite. The gangue, which is quartz, is scarce. The veins contain, besides quartz, pyrite, a little blende, native sulphur and arsenic [28/p. 424]. The country rock is stated to be granite [9/p. 225]

Germany

Mercury ore deposits are not abundant in Germany, and those which were formerly important have been worked out.

In the eastern portion of the Saarbrucken coal-basin deposits of mercury ore have been found as impregnations in slates, sandstones, ironstones and conglomerates of Lower

Permian age, as well as in the altered olivine-basalts, amygdaloids and porphyries, which have in various places broken through them.

At the Potzberg, in the Palatinate (Pfalz), veins occur in Carboniferous sandstone and argillaceous shale ; at Mörsfeld in altered olivine-basalt-conglomerate, claystone-conglomerate and claystone , at Ratweiler, Erzweiler, and Baumholder in altered olivine-basalt and amygdaloid , and at Konigsberg, near Wolfsberg, in quartz-porphyry. These veins are sometimes accompanied by claystones and hornstones, which are otherwise unknown in the district, and therefore may be alteration-products of sandstones and ordinary clay-slates. While the lodes are metalliferous in claystones and hornstones, they become comparatively unproductive when they pass into other rocks. Sandstones and conglomerates sometimes contain rich deposits, but the clay-slates are nearly always barren. A curious exception, however, is the occurrence of cinnabar in the casts of fossil fish in the clay-slate at Munsterappel, on the right bank of the Appelbach. Cinnabar is the chief mercury mineral, and usually occurs in thread-like stringers, or as crystals in small drusy cavities, either in the vein or the country-rock. The other mercurial contents are native mercury, silver amalgam, calomel, metacinnabar, and occasionally mercurial fahlore (tetrahedrite). Generally, the lode-filling is clay, but calcite, barytes, quartz, hornstone, chalcedony and bitumen are also sometimes present. The associated minerals are pyrite, red and brown hæmatite, siderite, galena, tetrahedrite, chalcopyrite, stibnite, pyrolusite and psilomelane. At Landsberg, on the Gottesgaben lode, the length of the mercury ore deposits is 2,700 ft. and at Mörsfeld 1,200 ft. The other deposits rarely exceed 600 ft. in length. The mercury content diminishes rapidly in depth, none of the stopes reaching 650 ft. below the surface. These deposits yielded large quantities of mercury in the past, but the production in recent years has been quite small.

Near Hartenstein, N.E. of Schneeberg, in Saxony, a cinnabar deposit, which has been known since the sixteenth century, presents some interesting features. According to H. Müller]51], the deposit is in certain beds of greenish-grey and dark-

green clay-slate, approaching talcose or chloritic schist in appearance Beck describes the rock as chloritic clay and hornblende-slate of the phyllite formation [52/p. 358]. This rock is besprinkled with hæmatite and contains kidneys and stringers of quartz, felspar, calcite, dolomite and siderite. The cinnabar is found impregnating the quartz, and is sometimes associated with pyrite and chalcopyrite therein, but is seldom found impregnating the rock itself.

The blende ores mined near Bensberg, in the province of Rhineland, yield annually about 90 flasks of mercury, won as a by-product in zinc smelting [2/1917]

HUNGARY

According to Von Cotta [53/p. 298], cinnabar occurs at Schemnitz, now in Rumania, in pyritous quartz, but it is rare. Elsewhere in Hungary the mineral has, in some instances, been deposited on stibnite [9/p 224].

The annual production of mercury in pre-war years was about 90 tons. Hungary, so far as known, produces no mercury now, for the siderite deposits, containing mercurial tetrahedrite, mined near Iglo, now belong to Czechoslovakia.

ITALY

The mercury ore deposit of Idria, in Carniola, formerly part of Austria, was discovered in 1470. It was worked by various companies until 1580, when the Austrian government took charge of the property. In 1865 the latter, believing the various mines (described below) to be approaching exhaustion, endeavoured to sell them, but failing to find a purchaser, resumed operations. From 1867 to 1879 the net profit amounted to nearly one million sterling, and in 1891 the reserves were estimated at 900,000 tons of ore. If these figures be correct, the mines have even now about 30 years of life. At the end of 1918 the mines were being worked by the Austrian technical staff under the supervision of Italian engineers, and the entire output was requisitioned by the Italian Ministry of War [2/1918]. On November 12, 1920,

the mines passed definitely into the possession of the Italian Government [2/1920].

The structural features of the deposits are very complex, owing to the existence of faults and extensive overthrusts. The main lines of stratigraphy were established by von Lipold [54], in 1881 he published his monograph on the mines [55] to commemorate the 300th anniversary of the Government possession, and complete geological details have since been worked out by F. Kossmat [56].

The strata met with in the mines (numbers 7 and 2, below, excepted), commencing with the most recent, are as follow

No	Age	Beds	Deposits
11.[1]	Upper Trias.	Cassian	Limestone
10.	"	Wengen.	Limestone-dolomite-conglomerate and breccia (derived from the Cassian and still newer Railer beds)
9.	"	"	Skonza shales and sandstones of *Lagerschiefer*
8.	"	"	Hornstone tuffs and marly slates.
7	Lower Trias.	Guttenstein or Muschelkalk.	Nodular limestone with chert.
6.	"	"	Dolomite and breccia
5.	"	"	Limestones and calcareous shales (partly Campiler)
4.	"	"	Calcareous shales (Campiler)
3.	"	Werfen.	Sandy calcareous and dolomite shales (Seisser)
2.	"	"	Quartz sandstone (Gröden).
1	Carboniferous.	"	Gailtal slates or *Silberschiefer*

[1] The numbers given here are identical with those of the official publication [57]

In Tertiary times the strata were subjected to enormous lateral compression, whereby all the formations have been disposed in zones. The main fault has a general N.W. to S.E. strike, and can be traced from Kanomla to Jélicen. It has left the Carboniferous Gailtal beds in concordance with the Triassic and even the Cretaceous sedimentary rocks. There are other parallel faults on the north and south sides, and a few which have a direction at right angles to these.

In the North-West mine, Werfen beds occur near the surface, and also form the floor of the ore-bearing beds, but they themselves are barren. Dolomite, dolomitic schist and lime-

stone (Guttenstein beds) form the immediate floor of the deposit. On the Guttenstein dolomite and breccia lie tuffs and marl-schists with hornstone, and the plant-bearing Skonza beds (*Lagerschiefer*), which are rich in cinnabar and consist of dolomitic sandstone and dark bituminous shales. These are overlaid by dolomitic conglomerate and breccia (Wengen beds), impregnated with cinnabar, when in contact with the Skonza beds. Then come the Cassian beds (limestone), and still nearer the surface, the abnormal overthrust Gailtaler slates (*Silberschiefer*—called so from the native mercury associated with pyrite which they carry at and near the contact with the Skonza beds—they rarely show traces of cinnabar).

The tuffs and marl-schists and the Skonza beds on the S.W. side, as seen in cross section, are bent downwards or have a N.E. dip of about 40°, from the level of the Antoni adit to a vertical depth of 755 ft. Here they are split into two branches, which are bent upwards, or dip in a contrary or S.W. direction from 35° to 47°, to level 4, a vertical depth of 312 ft., where they again unite, and are again bent downwards with a dip of about N.E. 60°—in other words, the cinnabar-bearing beds have a saddle and trough formation.

This formation, closed to the N.W., sends out four separate layers or branches to the S.E., three of which gradually wedge out in that direction, while the fourth continues right across the Idria mine. The branches are parallel in strike with the chief fault-fissures. The trough and saddle are covered by ore-bearing dolomite-conglomerate and breccia (Wengen) and, later, by the Cassian beds.

The Skonza shales (*Lagerschiefer*) are the carriers of the richest ore, but they are not everywhere equally rich; they may carry sterile partings, especially if the dolomitic and siliceous ingredients change to sandy shale and sandstone. The workable thickness is up to 66 ft. The richest ores are found in a highly bituminous, soft black shale, sometimes in most irregular lenses, nodules, stringers and nests, and at other times in lenticular masses between the bedding- and fissure-planes. Steel, liver and coralline ore (described hereafter) are found here; cinnabar also sometimes is found as a coating, or it may be finely scattered.

In the Skonza beds the deposit has the character of a bed (*Lager*), but it may be described as a stockwork in the dolomite conglomerate and breccia.

In the South-East mine the Skonza beds are considerably less developed than in the North-West mine. They, together with the tuffs and marl shales (Wengen beds), appear as a trough in cross section. The Skonza beds themselves are only in very thin bands, containing cinnabar, either solid or as impregnations. They lie usually upon Guttenstein dolomite, limestone and calcareous shale, and are capped by the Upper Triassic limestone (Cassian beds). Ore is extracted from a zone of impregnated rock lying along the bedding-plane between the Guttenstein dolomites and the Wengen marly shales

In this section of the Idria mines, however, cinnabar occurs principally in fissures which traverse the sedimentary rocks. Two principal veins strike N.E. and dip S.E. from 28° to 30°. The vein-filling—up to 3 ft. in thickness—consists of calcareous, argillaceous and breccia-like rock, heavily impregnated with cinnabar (steel and brick ore). Cinnabar also impregnates the fissures and crevices of the dolomite forming the hanging- and foot-walls. There are, besides, two thin hanging-wall veins, striking N.W. and dipping 75° N.E. One of these, parallel with the main fault-fissure of the Guttenstein beds, has a thickness of 1½ ft. of dolomite-breccia (friction-breccia) with much cinnabar. The same mineral fills the fissures and crevices of both hanging-wall (massive dolomite) and foot-wall (dolomite-breccia). The second vein follows the contact of the Guttenstein and Werfen beds, and is only a narrow fissure filled with a friction-breccia of marl and fine sand, impregnated with cinnabar. The hanging-wall (dolomite-breccia) also contains cinnabar, while the foot-wall (tough dolomitic-schist) only carries cinnabar and metacinnabar in the bedding and fissure-planes.

There are four recognized varieties of ore: (1) Steel ore (*Stahlerz*), the richest. It occurs in a compact and crypto-crystalline form, containing some bitumen, and carries 75% mercury; (2) Liver-ore (*Lebererz*) or hepatic cinnabar, a bituminous earthy variety, often forming the kernels of *Stahlerz*; (3) Coralline ore (*Korallenerz*), a curved lamellar

variety of (2) It is usually found in grit, and appears as singular petrifications having the form of corals. It contains 2% cinnabar, 5% bitumen, and 56% phosphate of lime [26/p. 480]; (4) Brick ore (*Ziegelerz*), sandy, granular, and of a bright-red colour. It contains 68% mercury when pure, and is mixed with dolomite, some quartz and native mercury, but is free from bitumen. It always occurs at the margins of the deposit.

The average grade of the ore mined at Idria is low, being between 0·75 and 1% mercury. The metalliferous associations are few, consisting only of calomel, metacinnabar [58] and pyrite, which only occurs here and there. There is seldom any gangue, but when it does occur, it is formed of calcite, dolomite or quartz. Barytes and fluorspar are rare. In addition, idrialite (hydrocarbons, mixed with cinnabar, clay, etc.), anthracite and graphite occur in the form of compact masses. Secondary minerals are epsomite, halotrichite (an iron and aluminium sulphate), melanterite (or green copperas), a ferro-sulphate and gypsum (sometimes as selenite).

The ore-bearing belt has been disclosed for a length of 4,600 ft., but the ore-bodies do not extend apparently much below 1,000 ft. in depth. The faults of the region are of Tertiary (probably Eocene) age, and the cinnabar deposits must be still more recent. A. Schrauf believes that the ore in the dolomite is a later migration from deposits in the shales [59/p. 466].

The deposits are practically confined to the Skonza shales, because the latter happened to form the centre of the fault-block, which resulted from the enormous compression that took place. In the compression they were more or less completely folded, fractured and broken up, and so afforded an easy channel to the hydrothermal circulation which followed, the bituminous matter in the rock no doubt aiding the precipitation of the cinnabar. As a matter of fact no cinnabar is found in the solid limestone and dolomite except along the bedding planes, or where these have been fissured or crushed into conglomerate and breccia, and then only in contact with the Skonza shales.

Cinnabar was worked by the ancient Etruscans, who used

the ore simply as a colouring matter, and again in mediæval times (1200 to 1300). The mines were afterwards closed down, owing to war and pestilence, and were not reopened until 1846. From 1856 and 1870 the Vallalta deposit, west of Idria, produced 9,550 flasks, but the mine has long been idle. The deposit is described as occurring at a contact between quartzose porphyry and Triassic sandstone, shale and conglomerate [60], [2/1917]. From 1860 to 1874 the Siele deposits alone were worked. In 1875 the Solforate Schwarzenberg began producing, but was closed down in 1886. Cornacchino began to produce in 1880, Montebuono in 1887, and Abbadia San Salvatore in 1899. In 1906, 1908 and 1909 the Solforate Roselli, Petrineri and Morone deposits, respectively, were first opened up [61], [3/p. 340]. There are at present eight active mines. Three have lately been worked out and abandoned, but have been replaced by the opening out of two new ones.

The ore-producing zone of Monte Amiata [62 to 67] has a length of about 25 miles, is parallel to the Apennines, and covers an area of 150 sq. miles. According to A. Verri [67], the cinnabar appears to be impartially distributed among Mesozoic sedimentary rocks (Cornacchino mine), Eocene marls (Siele and Solforate mines), Eocene sandstones and Nummulitic limestones (Montebuono and Cortevecchia), Pliocene sedimentary rocks (Saturnina), and even amongst trachyte (Abbadia San Salvatore). It appears that the deposits cease to be payable at a depth of about 600 ft., hence the future of the region lies in the extension, rather than in the extreme depth, of the producing zone [68].

In the Cornacchino mine cinnabar is found principally in limestone of Upper Lias age, filling previously formed cavities in the rock, usually arranged along certain definite lines of fracture, which are frequently connected with cross-fractures or crevices. The deposits may be said to be formed of irregular masses of cinnabar-bearing clay, mixed with marcasite, gypsum (amorphous and crystalline), and detrital limestone and quartz. Sulphur is accidentally present with the cinnabar. Immediately below the limestone is a highly siliceous rock about 160 ft. thick. This "flint-rock" (a

siliceous schist according to B. Lotti) is crossed by a number of little veins, which enter the limestone above, and communicate with the masses of cinnabar-bearing clay found therein.

The veins in this highly siliceous rock are usually filled with yellow clay, the colour being due to the oxidation of pyrite. When the clay, in the nests or pockets of the limestone, is black in colour, it is usually unproductive, but is regarded as a useful indicator, as it always occurs near deposits of cinnabar.

The grade of the ore is from 0·35 to 1% mercury, of which 15 to 20% is not recovered in the reduction plant. The output is about 120 flasks per month.

In the Siele mine [63], [69], [70], the deposits are found in the Eocene formation, in large beds of more or less argillaceous limestones, alternating with calcareous argillaceous schist and clay, having a general E N.E. direction, and dipping about 35° N.N.W The limestone is crossed by numerous veins of cinnabar. According to Meneghini (quoted by [63]), the veins are (*a*) E.–W., or nearly parallel to, but dipping contrary to, the strata ; (*b*) parallel to both dip and the strike of the country (*tettoni*) ; (*c*) N.–S. ; (*d*) N.E.–S.W. (*liscioni*) In the first three cinnabar is associated with calcite, and all three are contemporary with the origin of the deposit, while those of (*d*) are of later origin, and have clay as gangue. According to De Ferrari [63] the ore is composed of little grains and crystals of cinnabar, associated with marcasite with somewhat bituminous clay, and accompanied by a little calcite, gypsum, traces of alkali and of titanic acid, and microscopic fragments of quartz. The average grade of the ore is about 2% mercury, and the normal production about 375 flasks per month

The Solforate mine takes its name from a strong emanation of sulphuretted hydrogen that occurs in the locality. The formation is Eocene, and consists of limestone, schist and sandstone The deposit consists of masses of cinnabar-bearing clay with pyrite striking N W.–S.E., and accompanied by veins more or less parallel to the country. The average grade varies from 1 to 3% mercury.

In the Montebuono mine, according to R. Rosenlecher [71], Miocene sands overlie and conceal Nummulitic limestone.

At a depth of 100 ft. a great vertical crevice about 6 ft. wide was struck, filled with Miocene sands and clays, impregnated with cinnabar in an extremely fine state of division. In the immediately neighbouring rock are several funnel-shaped cavities, also filled with metalliferous sands and clays, the proportion of cinnabar increasing with the depth. These funnel-shaped cavities appear to bear some analogy to the vertical pipes or holes (*trojas*) in gypsum at the mercury mines of Huitzuco, Guerrero, Mexico (*see* p. 64). Broadly speaking, the whole deposit forms a large funnel, the position of which is marked on the surface by a distinct depression [26/ p. 473]. The cinnabar deposits occur near the contact with limestone, and pyrite is associated with the cinnabar. Limestone occurs in fragments in the Miocene sands, and carries veins of calcite. The age of the deposit as a whole is most probably post-Pliocene, and if so, it is more or less contemporaneous with that of the mercury deposits of California. The percentage of mercury varies from 0·2 to 0·6, and the normal production is about 40 flasks per month. The mine is not worked during the summer.

In the Abbadia San Salvatore mine stringers of cinnabar, accompanied by marcasite and opal incrustations, are found in trachyte, and, according to Kloos [72], trachyte tuff, lying on Eocene limestone, is cinnabar-bearing. In one of the old galleries many blowers (*soffioni*) of sulphuretted hydrogen and carbonic acid were met with. The mine was closed for some years, but it was reopened in 1899, and in 1919 was producing 25,000 tons of 1% ore from "columnar deposits of cinnabar." The principal deposits occur in Nummulitic limestone, especially in the bituminous clay beds. The reduction plant consists of 14 Spirek shaft furnaces and 6 Czermak-Spirek fine-ore furnaces, equipped with Czermak condensers. The normal output is about 1,700 flasks per month.

In the Cortevecchio mine the formation consists, according to B. Lotti [73], of great lenses of Nummulitic limestone, which, above and below, pass into clayey and marly beds. The chief concentration of ore occurs near the junction in these passage beds. Cinnabar has in part replaced the calcium carbonate of certain limestone-bands, and impregnates

generally the marly layers interbedded in the limestone. The ore is associated with pyrite and gypsum.

The Morone mine was worked in 1874 by Schwarzenberg, and was abandoned in 1882. It was reopened in 1909. The ore deposits are in the Nummulitic limestone, at its contact with shale, and are very argillaceous. The grade of the ore averages about 1% mercury, and the normal output is about 350 flasks per month.

In the Petrineri mine the ore contains 0·4 to 0·5% mercury, and the normal production amounts to about 60 flasks per month.

At Selvena black bituminous limestone of the Lower Jurassic formation is impregnated with cinnabar, stibnite, realgar and pyrite. At San Martino a red- or brown-coloured iron ore in Eocene strata is impregnated with cinnabar.

The following minerals are occasionally found associated with cinnabar in the Monte Amiata region. Native mercury (in drops in the cinnabar), metacinnabar; realgar and stibnite (mentioned above). Celestite is said to accompany the ore, as well as gypsum [62].

Primat [64] states that in certain parts of the Siele mine sub-sulphides of mercury, which may be represented by the formula Hg_2S, occur, which resemble soot and are called *neri* (blacks); a little native mercury is always found with neri. Dana [4] says that mercurous sulphide or *ethiopsite* (Hg_2S) is an unstable compound, and is not known to occur in nature, and, as no analyses are given by Primat, neri is most probably another name for metacinnabar, the black sulphide of mercury.

Other known mercury ore deposits in Italy, but not at present being worked, are at Arcaja, in Lucca; Monte delle Fate, in Pisa; Monte Loreto, in Genoa; San Quirico di Albaceto, in Parma, Marqua, in Como; and San Donata, in Cosenza.

A small production of mercury is obtained from the flue dust from lead-smelting at Monteponi, Sardinia.

From 1912 to 1918, inclusive, the production of mercury in Italy amounted to 7,266 metric tons, or an average annual production of 1,038 metric tons, the whole coming from the Monte Amiata region. In 1919 the output was abnormally

low, but in 1920 it amounted to 1,325 metric tons. This amount, however, includes returns from the Idria mines.

PORTUGAL

No mercury ore deposits of note are known in Portugal, but small amounts of mercury have been produced in the last few years.

A small quantity of mercury was yielded during the last century by a mine near Conna, not far from Lisbon [2/1917].

RUMANIA

Formerly the deposits of Zalatna in Rumania were worked for mercury, but these have been reported to be no longer productive (*see* p 38).

RUSSIA (IN EUROPE AND ASIA), INCLUDING UKRAINE

Some years ago the Russian deposits yielded a fairly large amount of mercury, the maximum output (616 metric tons) being reached in 1897; in 1910 it amounted to between 300 and 400 metric tons, but is stated to have dwindled to about 25 tons in 1911 There has been a small production since then.

In Southern Russia mercury deposits occur at Nikitovka in the Donetz coal basin, Government of Ekaterinoslav, now forming part of Ukraine. They were discovered in 1879, but were not actively worked until after 1886 According to von Ernst [74] and to Tschernyschew and Loutouguin [75], cinnabar is found in fault-fissures in coal, and as impregnations in the adjoining Carboniferous sandstone, quartzite and coal beds. The two principal cinnabar-impregnated beds consist of sandstone and quartzite. The sandstone has shale on the hanging-wall, and a very compact sandstone or quartzite on the foot-wall. Besides being impregnated with cinnabar, it has numerous small cracks or fissures also carrying the mineral. The quartzite has sandstone on both walls. The occurrence appears to resemble that at Almaden, Spain, but the cinnabar-bearing beds at Nikitovka dip somewhat flatly at the surface, although they are much steeper in depth. The sandstone bed is inter-

sected in the lower levels by a wide brecciated vein, whicl dips at a high angle in the opposite direction to the sandstone It recalls the *frailesca* breccia at Almaden, Spain (*see* p. 49) The cinnabar is associated with stibnite, pyrite, sulphur an stilbite.

From 1887 to 1892, inclusive, the ore treated produce 1,355 metric tons of mercury [76] In 1910, 90,000 tons o ore yielded 0·4% or 360 tons of mercury [19/1910, p 595 There was no production during the next four years, but th mines were worked during the war, or from 1915 to 191 inclusive (*see* table, p. 18).

In the Urals, deposits of mercury ore have been foun in the Verkh-Isset district, in the Ekaterinburg region. Th average assay of 57 samples was 0·61% mercury. A few c the samples gave 10% mercury. No production has bee recorded from this locality

Near Lake Ayamsk, 28 miles from Ekaterinburg, deposit of cinnabar are said to have been discovered containing 1% mercury. Lumps of cinnabar, weighing up to 1 lb. each an more, have been found in the Olene-Travyansk placer on th River Travyanka, 12 miles from the village of Karaoul. Simil lumps have been found in other placer mines in the Ural [77].

In the Kokand district of the Province of Ferghana, Russia Turkestan, deposits of native mercury and cinnabar hav been discovered [77].

A cinnabar deposit was worked at Nerchinsk, Siberi as long ago as 1759, but without success. According to vo Kokscharow, the cinnabar occurs in little veins, rarely exceedin 2 in. in thickness, near a granite eruptive rock. It is accon panied by galena, and the gangue is quartz and calcite [78 According to the Admiralty *Handbook of Siberia and Arct Russia*, deposits of cinnabar are said to occur in the Am basin, and in Kamchatka, Siberia.

SCANDINAVIA

The native silver of Kongsberg in Norway often contai mercury.

In the metasomatic silver-lead deposits at Sala, in Swede

silver-amalgam, native mercury, and in some places, cinnabar especially, occur, though only in very small amount [26/p. 462].

Spain

The Almaden mercury mine is the most important in the world; it has been worked for centuries, produces nearly one-third of the world's supply of mercury, and is unique in this respect that the deposit has increased in richness to the depth already attained (about 1,300 ft.).

Almaden [12], [13], [79] is on the northern slope of the Sierra Morena, in the Province of Ciudad Real. The formation consists of steeply upturned carbonaceous slates of Upper Silurian and Devonian ages, with intercalations of quartzites and grits. At Almaden the age of the country is Silurian, and, although cinnabar does occur in Devonian strata in the same region, no deposits of economic value have yet been found in those rocks.

As at Idria, Carniola, there has been considerable lateral compression, which has produced some singular foldings. There is evidence of this in the mines, especially in the fifth and sixth levels, and, in the midst of the quartzite here and there, are large lenses of schist, and in the schist occur blocks of quartzite or limestone. Various eruptive rocks exist in the region—principally altered olivine-basalt and dolerite. A rock, described by Kuss as a melaphyre (altered olivine-basalt), and by Molina as a porphyrite, was first met with in the eastern end of the sixth level on the San Francisco lode—in the eleventh level of the mine it practically forms one wall of the lode along the north side. A peculiar rock—called *piedra frailesca* by the miners from its grey colour resembling that of the habits of Franciscan friars—is found nearly at the contact with the cinnabar-bearing rocks, and is 160 ft. thick. The San Teodoro shaft, on the south side of the deposits, was sunk upon it, to about half-way between the tenth and eleventh levels, when schist was encountered. In the mine the *piedra frailesca* usually consists of angular fragments of black schist cemented by dolomitic limestone, with many druses lined with small rhombohedral crystals of dolomite. It occurs as a series of lenses intercalated in the schist. A little cinnabar

is found in veins and spots in the *frailesca*, which proves th: mineral to be of more recent origin than the breccia itsel Helmhacken and Calderon regard it as a dolerite tuff.

In the bottom levels, where the deposits are more regul: than in the upper levels, they may be described as formir three or more parallel lodes, in a band of schist and quartzit about 160 ft. in width, and under 820 ft. in length, which stril about E.-W. They have been followed vertically to a dept of about 1,300 ft. The lodes have not the ordinary characte istics of mineral veins, but may be described rather as banc of rock impregnated with cinnabar. The lode on the sout side, known as San Pedro and San Diego, is almost entire in dark carbonaceous schist with intercalations of quartzit while the two lodes on the north side, known as San Francisc and San Nicolas, which are close together, and form practical one lode in the ninth level, are in quartzite, with intercalatio of schist. The ground between the northern and southe lodes consists of quartzite, with some thin bands of schis The wall on the south side is composed of carbonaceous schis except along the eastern half of the lode (known as San Diegc where it is formed of quartzite. The wall on the north si is quartzite along the eastern half, and schist along the weste half. The black carbonaceous schist carries isolated banc of white magnesian limestone (dolomite), which also occu as veinlets and stringers in the middle of the mass of tl rock, and sometimes contains beautiful little crystals cinnabar [12/p. 17].

The lower workings have proved that in depth (1) Tl deposit has become straighter; (2) the ore-bearing portic has increased in length, (3) the ore has become richer; (. the thickness has increased, (5) the ore-bearing portion h: advanced rapidly towards the west, and has retired, althoug not in a corresponding degree, towards the east—this wou appear to indicate that the shoots of ore have a wester pitch; (6) the thickness of the band of slate has decrease in the north, so that there is almost contact between tl altered olivine-basalt and the deposit, and has increased i the south, where it takes the place of *frailesca* [13].

The average thickness of the San Pedro and San Diego loc

is about 36 ft. The deposit consists of white grit, regularly impregnated with cinnabar of a bright-red colour. San Nicolas and San Francisco (northern lodes) are 10 and 13 ft. in thickness respectively. The grit of these deposits is black, and harder and more compact than that of the southern lode, and at the same time the ore is less regular, less rich and darker in colour [12/p. 31]

It was supposed by G. F. Becker that the mercury had penetrated the grit on account of its porosity, and not by substitution, but R. Beck has shown convincingly that there has also occurred an actual replacement of the sandstone grains by the ore mineral [59/p. 465]. Moreover, occasionally, the schist is seen to be entirely replaced by cinnabar in shapeless crystals, and, more often, in masses having a sedimentary appearance, and schistose like the primitive rock [12/p 41].

Pure crystallized cinnabar is rare, and, when it does occur, it is usually accompanied by small crystals of quartz, barytes and pyrite. Amorphous cinnabar (containing 75 to 85% mercury) is much more common, and is disseminated in an irregular manner in the middle of the cinnabar-bearing grits, especially in the southern lode. The minerals associated with the cinnabar are, as at Idria, few in number and small in quantity. Pyrite and chalcopyrite are very rare—the former is sometimes surrounded by cinnabar. A certain proportion of silica may be said to form the gangue. Bituminous matter is present here and there, which no doubt helped the precipitation of the cinnabar. Calomel and native mercury are rare—the latter has been found by itself in a very schistose quartzite.

Certain quartzoze and schistose breccias are cemented by cinnabar, which is associated with dolomite and barytes. This may be regarded as evidence that the mercury ore had a hydrothermal origin.

The miners divide the ore into three classes: Poor ore (1 to 7% mercury); average ore (8 to 20%); and rich ore (20 to 85%). The average content of the whole of the ores mined and treated is said to be about 8%. The upper levels (Nos. 1 to 4) of the mine caved in long ago, but it is said that the ore extracted from them was by no means rich. Average

ore was met with at a depth of 620 ft. (No. 6 level), and rich ore at a depth of 705 ft. (No. 7 level); at first in small quantities only, but it was the predominating ore at a depth of 860 ft (No. 9 level), and below this it constitutes almost the entire filling.

When schist is in contact with black grit, cinnabar is found sometimes in the cavities of the schist, or in little veins between its leaves. Sometimes the cinnabar passes abruptly from one bed to another. According to H. Kuss, the San Francisco lode, in one part of the fifth level, is thrown 20 ft. towards the north without the beds of quartzite participating in the throw. This appears to be a case of overlap or splice.

To account for the deposit we may suppose the quartzite to have been fissured and shattered along certain nearly parallel E.–W. lines. Solutions bearing sulphide of mercury have made their way through narrow fissures in the rock into the crushed zone, filling the cavities and fissures therein, and here and there replacing the country-rock. No doubt the deposit is connected genetically with an eruptive rock.

Kuss believed the deposits to be older than that of Idria, Carniola, and to be of the same age as those of the Palatinate, Germany.

The following table shows the production of mercury at Almaden from 1564 to 1919:

Period.	Tons (metric)	Average number of metric tons per year
1564–1700	17,863	103
1700–1800	42,149	421
1800–1875 . .	60,166	802
1876–1919 . . .	43,000 (estimated)	1,000 (estimated
Total . . .	163,178	

In 1917 the actual yield at Almaden was 5·7%, but the working cost amounted to nearly £9 per ton [19/1919, p 618]

At Mieres, near Oviedo, in the Province of Asturias [80] are some mercury mines which were worked by the Romans and which were reopened about 1840. Cinnabar occurs as a

stockwork in grit and Carboniferous quartzite, particularly impregnating a breccia formed of fragments of these rocks. In 1911 the average content was 0·7% mercury [61/p. 82]. At Pelugano the deposit occupies a fissure, of which the Mountain Limestone forms the hanging-wall and the Devonian quartzite the foot-wall. At Lada cinnabar is found impregnating three seams of coal and Carboniferous conglomerate. At various other places in the province red cinnabar and metacinnabar occur associated with realgar, orpiment and metallic arsenic in limestone, sandstone and metamorphic schist [80]. In 1915 the production from the Oviedo districts was 608 flasks [3/p. 360].

At Usagre, Bienvenida, Province of Badajoz, cinnabar occurs in quartz veins in Cambrian limestones. The associations are copper sulphide ores, siderite and rhodochrosite. The limestone is occasionally impregnated with cinnabar. The grade, which was formerly 1·24% mercury, has been increased in recent years. Two new Bustamente furnaces were in operation in 1918. The output is about 40 tons of mercury per annum.

On the southern slope of the Sierra Nevada, Province of Granada, there are numerous small and irregular veins, containing cinnabar, in talcose schists of Triassic age, accompanied by tetrahedrite, sulphides of nickel and cobalt, and iron oxides [81]. The cinnabar is contained in iron oxide incrustations on calcite, and the content varies from 0·7 to 2% mercury. Here also are two Bustamente furnaces. The production from Granada in 1915 was 41 flasks.

In the Province of Santander cinnabar forms pockets in the lead and zinc ores.

In the Province of Valencia cinnabar occurs as veinlets in sandstone. The filling consists of cinnabar intimately mixed with quartzite and calcite, and with abundant pyrite [81]. Hitherto all attempts to treat the ore have failed [61].

YUGO-SLAVIA

The principal mercury deposits of the State are in Bosnia, Serbia and Slovenia (Carniola).

Bosnia

The cinnabar deposits of Zec Planina, north of Kresevo, and 22 miles west of Sarajevo, Bosnia, are associated with nests, stockworks and beds of hæmatite (probably of metasomatic origin) in Upper Permian limestone. The cinnabar occurs very sparingly within the hæmatite ore, the richest places being usually just above it in the roof or hanging-wall. The percentage of mercury in the ore ranges from 0·02 to as much as 30. The deposits proved to be largely superficial, and the mines are now closed

Near Kresevo cinnabar is associated with tetrahedrite, malachite and barytes in lenticular beds of hæmatite. At Dezavitsa, to the west of Kresevo, cinnabar occurs as impregnations in sulphide veins in limestone, close to intrusive masses of quartz porphyry.

At Cemernitsa, near Fojnitsa, there is a broad metalliferous belt with six principal veins, traceable for 1¼ miles, in close relation to intrusive masses of quartz-porphyry The lodes are characterized by three layers or bands. In the centre of the vein is very clear quartz with needles of stibnite, outside this is quartz carrying hæmatite and a little cinnabar, while the band next the walls is composed of quartz and stibnite. The mine was formerly worked for silver and gold. At Kahor, 3¾ miles north of Fojnitsa, cinnabar, associated with brown iron-ore and pyrite, occurs in quartzose veins in Carboniferous sandstones and shales. These veins appear to be intimately related to extensive masses of quartz and porphyry. At Drazevitsi, near Cevljanovits, cinnabar occurs in Triassic limestones and shales near intrusive masses of quartz-porphyries and dolerites. The richest impregnations were found at the faulted junction of the Werfen shales with limestones (Lower Triassic).

Maskara may be regarded as one of the most important centres of the mineral industry in Bosnia. The rocks consist of Carboniferous sandstones and shales overlaid by sandstones, limestones and conglomerates of Permian age, with intrusions of quartz-porphyries. The principal lodes, which strike N.W. to S.E. and are traceable for several miles, are inter-

sected by N.–S. veins (occasionally mineralized) and N.E to S.W. veins (barren). The filling of the principal veins consists of mercury-bearing tetrahedrite, siderite, barytes, quartz and calcite, with some dolomite, and rarely with pyrite, chalcopyrite, cinnabar and native mercury. Alteration products are limonite, hæmatite, malachite and azurite. An analysis of the tetrahedrite yielded the following percentages · Copper, 38·41; antimony, 27·43; mercury, 7·58; sulphur, 21·62; zinc, 0·72; iron, 2·80, magnesia, lead, arsenic, traces; gold, 0·005; silver, 0·152. Mercury is always present, and in some specimens the content reaches as high as 16%. The main lode has been worked to a depth of 328 ft. from six principal levels [82].

Dalmatia

Cinnabar is found at Spizza, Dalmatia, associated with stibnite, in veins traversing Triassic limestones and dolomites. The deposit was worked on a small scale in 1900 [82].

Serbia

In the Mt. Avala region [82], [83], [84] mercury ore has been mined in numerous places. From 1885 to 1891, 7,796 tons of ore, with an average content of 1·4% mercury, yielded about 80 metric tons of mercury. This district is underlaid by Cretaceous marly limestones, in which are intruded biotite-trachytes and massive serpentines. The ore occurs in quartzose veins upwards of 230 ft. wide. At the southern end of the district the serpentine crops out against the Cretaceous limestones, forming a rocky bar, known as the "lower vein," which carries a little cinnabar and galena. The serpentine rock was completely altered and replaced by quartz, opal and dolomite. The cinnabar is generally found in the quartziferous sandstone, at and near the margin in the form of impregnated veins of cinnabar, galena and some pyrite, from 6½ to 49 ft. in width. Other associations are dolomite, magnesite, quartz and avalite (a muscovite rich in chromium). At Schuplje Stena there is a quartzose lode from 197 to 230 ft. in width, striking N.E.–S.W. and dipping N.W. 60°. The main vein is crossed by numerous E.–W. quartz-barytes

lodes carrying small quantities of mercury ore. Besides cinnabar, there are small quantities of native mercury and calomel [52/p. 357], [82]. The quartz of the main vein resembles hornstone, and is impregnated along well-defined zones with pyrite and scales of avalite.

The deposits are said to have been worked out [61], but, according to Wray [82], the present suspension of the mines is mainly due to the fact that the deposits on the whole are of small extent, and do not offer any prospect of improvement in depth.

Serbian Macedonia

Cinnabar occurs in veins in the Triassic limestones at Priszen in Serbian Macedonia, where it is associated with metallic sulphides.

Slovenia

The Potoknig mines of Carniola are near Neumarktl, 31 miles north of Ljubljana (Laibach). The geological formation is similar to that at Idria (*see* p. 39), but the strata here trend E.–W., and are tilted on end. First, there is Guttenstein limestone (originally on the top); then Werfen beds; then Gailtal (Wengen) beds. The last consist of an upper limestone, of a middle black limestone traversed by veins of calcite, and of grey and brownish ferruginous marls and slaty limestone. The cinnabar occurs in the central black limestone, which is highly bituminous, either as nests or stringers in a calcareous breccia, which fills joints and fissures in the rocks. From 1760 the mines yielded a small output for upwards of a century, the grade of ore varying from 0·65 to 1·2% mercury [53/p. 343]. In 1891, 6,000 metric tons of ore yielded 21 tons of mercury [28/p 440]. The mines are now abandoned [82].

At Litija (Littai), also in Carniola, cinnabar occurs associated with lead ores in a zone of brecciated shattered rock, 10 ft. thick, in what is known as Gailtal greywacke (Carboniferous). The ore-body consists of much altered fragments of greywacke and nodular pieces of siderite, cemented by galena; there are also present some blende, barytes, chalcopyrite and pyrite. The cinnabar forms a coating on kidney-shaped pieces of galena

in the brecciform rock, and also in and near fissures which are considered of later age. Fuchs and De Launay regard the cinnabar as of more recent date than the galena in the shattered rock; the cinnabar mineral having probably followed the reopening of the fissures [52/p 355], [82], [85].

For some time about 15 metric tons of mercury per annum were obtained as a by-product from these lead mines. The ores of mercury were found, however, to disappear in depth [82].

At Kappel, 18½ miles S E. of Klagenfurt, Carinthia, cinnabar, disseminated in green and red metamorphic schists, has been exploited on a small scale, and further north, at Reichenau, in the Drave Valley, cinnabar, accompanied by magnesite, occurs in nests in altered schists [82].

The only mercury produced in Yugo-Slavia in recent years has been that recovered as a by-product in the treatment of tetrahedrite.

ASIA

Asia Minor

Ancient workings near the town of Konia, in Anatolia, which may have been worked by the Phrygians as a paint mine 3,000 years ago, have been reopened and profitably mined in recent years. In the Konia mine [86 to 89], which is at an altitude of 5,900 ft., the deposit consists of a number of stringers of cinnabar in more or less silicified limestone, near talcose-schist, and at no great distance from old eruptives, and contains 1 to 2·5% mercury. In one orebody the cinnabar is associated with stibnite, which carries about 8% mercury. In 1908 the known reserves were estimated at 13,000 metric tons of 1% ore [3/p. 341]. The output was good in 1913, but no statistics have been available since. The plant included a Spirek shaft furnace for coarse ore, and a Czermak-Spirek roasting furnace for fine ore, the daily capacities being 15 and 8 tons.

Several cinnabar deposits occur in the N.E. of the Kara Burun Peninsula, Territory of Smyrna. According to D'Achiardi [90], a highly metamorphic dark schist is traversed

in a north and south direction by a quartzose brecciated rock, 26 ft. in thickness, carrying 2¼ to 2½% mercury. The schist abuts against a Cretaceous Hippurite-limestone, 300 ft. to the east, and is cut off by basalts on the west Cinnabar-bearing quartz cross-veins occur in the schist near the limestone. Microscopic examination shows that the cinnabar was deposited simultaneously with the siliceous cement of the breccia. This breccia was mineralized by siliceous water containing in solution salts of mercury and iron which found its way through rock fissures originated by the basaltic eruptions.

Before the war the Konia and Kara Burun mines were worked by a British company At the latter mine the rock was quarried, and ore carrying as little as 0·25% mercury was treated at a profit. The yearly production in 1906 and 1907 was about 3,000 flasks. The output has declined of late years, being 90 and 811 flasks in 1911 and 1912 respectively [3/p. 341]. The plant consisted of two double Spirek shaft furnaces for broken ore, and a Czermak-Spirek furnace for fine ore. The capacity was 30 tons per day [87]. The plant first went into operation in May 1906. The average ore mined during the first year of active mining operations contained 0·75 to 1% mercury.

The total production of mercury per year in Anatolia is estimated at between 4,000 and 5,000 flasks [87]. In 1909 the Turkish production of mercury amounted to 142 tons (3,786 flasks) only.

During the war the mines of Asiatic Turkey came under German control, and it is reported that the Deutsch-Turkische Montangesellschaft purchased or rented all accessible mercury mines in Asia Minor, including a mine at Odemish in the Vilayet of Smyrna.

A deposit of mercury ore at Oshak, recently discovered, is reported to contain considerable quantities of ore of excellent quality, but further particulars are lacking.

China

Deposits of mercury ore are reported to occur in many parts of China, but at the present time the only mines known

to be of any importance are those of Yuan Shan Chang, in the S E. part of Kweichow Province.

According to Henry Brelich [91], the ore at Yuan Shan Chang occurs in nearly horizontal beds of magnesian limestone : (1) Impregnating well-defined beds ; (2) along joints, cracks, and planes of stratification , (3) in isolated bunches, vugs, etc. , (4) irregularly disseminated through beds which in most cases have undergone local disturbances. There are two kinds of cinnabar, the colour of one being bright-red ; and that of the other dark opaque-red. Small amounts of stibnite are associated with the latter. Pyrite is absent, although it usually accompanies cinnabar in Kweichow [28/p. 448].

The ore is mined and treated in a very primitive manner, and the produce is chiefly converted into vermilion, which is used locally as a pigment. In 1899 a European company commenced operations in the Kweichow Province, and erected two Granzita furnaces for treatment of the lower-grade ore, but, owing to difficulties with the Chinese authorities, little progress has been made, and it is stated that in 1908, when the concession expired, a renewal was refused [19/1909, p. 620]. Samples of the Yuan Shan Chang ores contained 1·7 to 4·4%, and averaged 2·78% mercury. For several years prior to 1905 the output averaged about 640 flasks annually [3/p. 341].

Cinnabar is said to exist in Western and Northern Yun-nan , in the beds of streams entering the Salween, Mekong and Yangtze rivers, in Western Kweichow, Singyifu district, and in other localities, but no production is known outside the Yuan Shan Chang district.

Recent productions of mercury in China will be found in the table on page 18.

JAPAN

The Suigin mine at Suii, in Awa, Shikoku, appears to have been the only mercury mine in operation in Japan in recent years. Here cinnabar, associated with calcite, is found along a fault fissure in Mesozoic limestone as veinlets and impregnations [2/1917]. On the island of Hirado cinnabar occurs in an impregnated bed of Carboniferous sandstone [26/p. 487].

New Caledonia

Deposits of mercury ore carrying from 1·75 to 2·75% of the metal occur at Bourail, Canala, Konaona and Piwaka, in New Caledonia, but are not at present worked [31/p. 487].

Persia

Mercury ores are known to exist in Persia, the chief occurrences being in the district of Takht-i-Suleiman, where the minerals are cinnabar, native mercury, orpiment and realgar. The last two minerals are found also in Persian Kurdistan [92/No. 1177, p. 70].

AFRICA

Algeria

For some years past small quantities of mercury have been exported from the Taghit mine, about 26 miles from Batna. Here veins of blende and argentiferous galena, containing cinnabar, occur in limestone of Upper Cretaceous age [93], [28/p. 445] Calamine and siderite are other associates. The grade varies from 1·2 to 1·5% mercury, and from 5 to 15% zinc [31/p. 483]. This mine was one of the first to erect Czermak-Spirek fine-ore furnaces for the treatment of the mixed ore. Spirek also modified a coarse-ore shaft furnace and reverberatory furnaces for treating lead ore, so that they serve not only to roast the ore, but are at the same time adapted to the recovery of mercury [61].

At Bir-Beni-Salah, 6 miles south of Collo, cinnabar occurs with galena in gneiss; at Ras-el-Ma, 6 miles S.W. of Jemmapes, are cinnabar-bearing bedded-veins with barytes, at the contact of marls and Nummulitic limestones; the antimony veins at Hamimat and Djebel-Taya contain a little cinnabar; and at Djebel Souhabâ, 23½ miles S.W. of Souk-Arrhas, are fissures in marls and limestone (Gault and Cretaceous), which enclose cinnabar, either alone or with galena and blende [28/p. 445].

Italian Somaliland

The presence of mercury ore has been reported in the north of Italian Somaliland [30/No. 128, p. 22].

Tunis

Deposits of a similar type to those of Algeria occur in Tunis, *e g.* cinnabar occurs in fluorspar veins in Jurassic limestone at Djebel Oust, associated with tetrahedrite and azurite [28/p. 445].

Upper Senegal and Niger

Mercury ore has been found in the Bambouk region of Upper Senegal [30/No. 107, p. 39].

NORTH AMERICA

The mercury deposits of North America are to be found entirely in the Cordilleran region from Alaska to Central America.

Honduras

Mercury ores have been known in the republic of Honduras for many years, and in 1909 a production of 138 flasks was recorded. In the Department of Comayagua a rich deposit of cinnabar was known during the Spanish occupation, which apparently has not yet been exploited [19/1909, p. 620].

Mexico

Deposits of mercury ore are numerous in Mexico, and are known in the States of Chihuahua, Durango, Zacatecas, San Luis Potosí, Guanajuato, Querétaro, Hidalgo, Jalisco, México, Michoacán, Morelos, Guerrero and Oaxaca. The principal deposits occur in the states of San Luis Potosí and Guerrero. They vary in character, but in nearly all cases appear to have resulted from the action of hot mineral springs, being found in regions bearing unmistakable signs of volcanic disturbance.

San Luis Potosí.—The most notable occurrences of mercury

ore in Mexico are in San Luis Potosí, where are the Guadalcázar, Trinidad, Nuevo Potosí and other mines [94 to 98], and where production has been carried out for a large, but unknown, number of years. Topographically the mercury ore-bearing country is composed of a succession of nearly flat plains bounded by ranges of hills with a general N.W. and S.E. trend, which consist, for the most part, of limestone, cut by dykes of porphyritic rocks, chiefly andesites. In some of the wider and more complex ranges, a central core of granitic rocks is found, and the range running N.E. of Guadalcázar is of this type. The central core is separated by a depression from the limestone, which appears to be mineralized right through, in varying degrees, with mercury minerals. The limestone is slightly dolomitic and finely crystalline, and contains solution cavities. Closely associated with the limestone is a fragmentary rock, consisting of small fragments of limestone, generally somewhat siliceous, and frequently cemented by calcite and gypsum or by a tenacious substance of an argillaceous character.

Kaolinized material from decomposed granite dykes in the limestone is sometimes encountered, and gypsum beds are frequently interstratified with the limestone All these contain mercury as cinnabar, metacinnabar, guadalcazarite and another sulpho-selenide, not definitely identified. The gangue minerals are quartz, calcite, fluorspar, barytes and selenite. Native sulphur is also associated with the cinnabar The ore-bodies occur chiefly as thin stringers or leaders (sometimes in the form of "sheets" and "pipes"), often opening out into irregular pockets of considerable dimensions. Fissure veins are occasionally met with, but all the deposits appear to be connected with a system of fissures and fault-planes, which has not been well investigated.

At the Nuevo Potosí mine, San Antonio, the ore is chiefly cinnabar and metacinnabar, disseminated in the limestone. At El Quiote and Sta. Maria, the deposits appear to be true fissure veins in limestones, or very closely connected with fault fissures. At the Trinidad mine the largest ore-bodies are in gypsum, or in fissures with a foot-wall of gypsum and a hanging-wall of fault-breccia.

The Guadalupana mine is said by A. Capilla [99] to be one of the richest mercury mines in Mexico. There is a belt, from 20 to 30 ft. broad, of highly folded calcareous slates (or marls), which strike N.–S. and dip S.W.55°. The ore (cinnabar) occurs as small leaders or impregnations in the marls, associated with calcite and a little gypsum By 1904 a depth of 500 ft. had been reached, and the deposit had been followed for over 600 ft. along the strike. The average weekly output of ore at that time was 10 tons, assaying 10% mercury. The total production up to February 1903 was 3,194 metric tons of ore, from which 6,787 flasks of mercury were extracted—a yield of 7·22% [100].

The Dulces Nombres mine, north of the Guadalupana, has been successfully worked by an American company. The deposit is a remarkable one—probably unique of its kind. The mine was taken up in 1890. The formation consists of limestone of Lower Cretaceous age, which has been subjected to thrusts at right angles to the strike of the strata, *i.e.* against the dip, bending and folding the beds into small, irregular and distorted areas. When the acute angles of the folds point upwards, cinnabar may occur in the limestone as widely scattered pockets and stringers of high-grade mineral. The stringers occur in the joints and slips near the pockets, while the latter are more mineralized within the brecciated matter occupying the upper portions of the folds. When the acute angles of the folds point downwards, the limestone is never mineralized. There are no gangue minerals, but a very small amount of pyrite and gypsum may be noted now and then along the slips or in the gouge (clay selvage), which may partially surround the deposit at the acute angles of the fold. In certain workings there is a highly fractured vertical zone, which has been subjected to an intense oxidation. Here occurred a considerable amount of native mercury, calomel in colourless crystals and in white earthy masses, and the rare oxychlorides, terlinguaite and eglestonite, which were first discovered in Brewster Co., Texas. Percy A. Babb, who described these deposits in 1909 [101], thinks that the cinnabar had migrated from some other deposit of the usual type, and that the mercury sulphide had reached the zone of the

present workings as a gas, and was deposited as a sublimate. That the mercury salts have been interrupted in their ascension by the closed angles and folds in the limestone strata is evident. During 20 years more than 10,000 metric tons of the ore, yielding upwards of 14,000 flasks of mercury, have been extracted from this mine. In 1908, 785 tons of ore produced 700 flasks, a yield of 3·98% mercury. The rare mineral onofrite (mercury sulpho-selenide) occurs at San Onofre, in the same state [100].

Guerrero.—The mercury deposits of Huitzuco [102 to 104], State of Guerrero, occur in limestone of Middle Cretaceous age, which is bounded on the west by the andesitic eruptives of Nostepec and Tasco. According to E. Halse [102] they are of two classes: (1) Large loose deposits in limestone and gypsum or filling vertical pipes in gypsum, and containing the secondary ores barcenite and cinnabar, and (2) large cylindrical deposits of primary ore (livingstonite) in limestone, occasionally opening out into lenticular or ellipsoidal chambers or pockets.

(1) The filling of the surface deposits usually consists of sand, clay, fragments of limestone and gypsum-rock (rock-débris), with cinnabar, barcenite (both these are of secondary origin), and sometimes stibnite (primary). The vertical holes or pipes in gypsum appear to follow lines of faulting, are cylindrical or elliptical in plan, and go down to a depth of 100 to 130 ft. A few of the holes are funnel-shaped, but the apex of the funnel or cone does not reach the surface. In some the rock, forming the side of the holes, appears to have been worn into rings or ridges, perpendicular to the vertical axis, as if they had been formed by water having a violent rotary motion. The gypsum-rock is built up of thin layers, perpendicular to the axes of the holes, which are filled, sometimes with rock débris alone, and sometimes with "smalls" containing secondary cinnabar and barcenite in rounded pieces (called *trojas de metal* by the miners, from their supposed resemblance to the cylindrical adobe buildings used in the region for storing maize).

(2) The deposit of La Cruz had been worked to a vertical depth of 820 ft. in 1898. The longer diameter is directed N. 52° W., and the general dip is S.W. 45°, but, in cross-section,

the deposit is seen to pitch first N. 52° W., and lower down, S. 52° E. To a depth of about 100 ft. the deposit is capped by gypsum, containing the natural pipes already described; below this depth the primary ore, livingstonite, a sulphide of antimony and mercury ($2Sb_2S_3.HgS$) was found, associated with stibnite, in limestone with patches of gypsum, and, lower down, in gypsum with patches of limestone, and still deeper, in solid dark-grey limestone. Several irregular lenses or pockets of ore were met with, separated by more or less poor ground. The richest lens occurred in solid limestone at a depth of about 500 ft. below the mouth of the Trinidad shaft. The yield was at the rate of 75 tons of best ore (12% mercury), and 225 tons of ordinary ore (1·5%) per week Below this the ellipsoidal deposit enlarged considerably and became low-grade. The ore was extracted in immense chambers. The livingstonite is associated with stibnite, selenite and native sulphur. Metacinnabar is also said to occur [28/p. 459]. The limestone contains small cubical crystals of pyrite and some quartz, and is veined with calcite. The average grade of the lower portion of the deposit was about 1% mercury.

Juan D. Villarello [104] remarks that emanations of sulphuretted hydrogen have been observed, especially at a depth of 590 ft., and that the ore-body and the contiguous country-rock are impregnated with organic substances. He also states that the amount of metallic mercury and antimony diminishes as the workings are pushed deeper, varying from 5 to 10% in the upper levels down to 0·75 or 1% mercury in the lower levels, and from 40 to 10% antimony.

The deposit has obviously been formed by a thermal spring cutting its way to the surface, and in the process the limestone has, here and there, been changed into gypsum.

La Bella Unión mine is 1¼ miles south of La Cruz mine. Here, according to Juan D. Villarello [105], fissures frequently communicate with cavernous hollows dissolved out of the limestone by the action of surface waters, and sometimes by the action of thermo-mineral waters. The ore is cinnabar with a small quantity of metacinnabar and native mercury, associated with pyrite, calcite and gypsum forming the gangue.

Durango.—At the Palomas mine, State of Durango, 50 miles west of Durango City, there is a zone of contact between rhyolite and basalt. Contact-metamorphism has partly altered the rhyolite into a white clay. Within the clay occur irregular veins of amorphous silica, with which in places cinnabar is closely intermixed. Bituminous substances are found in various parts of the deposit, and also a small quantity of native mercury. The deposit is a shallow one, although traceable for 1,000 ft. The grade varies from 0·05 to 5% mercury [104].

Jalisco.—Mercury deposits occur at Chiquilistlán, 118 miles S.W. of Guadalajara, in the State of Jalisco. They were worked more or less spasmodically from 1843 to 1904, when a company was formed to work them on a proper scale. The formation consists of Middle Cretaceous limestone, overlaid by sandstones, clays and marls, with eruptive masses of hornblende-andesite. Fissures traverse the limestone in all directions, and the ores are chiefly found at the meeting points. The fissures are mineralized with cinnabar and chalcopyrite and the alteration products, azurite, malachite and limonite, the gangue being calcite and a little gypsum. The ore contains on an average 0·80% mercury. The thermal waters appear to have enlarged the original cavities in the rock and to have largely deposited their metallic constituents by metasomatic replacement [106].

Querétaro.—Some mercury deposits have been worked in the State of Querétaro. In the Cerros de los Cabras various nodules and stringers of cinnabar, forming stockworks in places, occur in limestone, which carries some native mercury. At Deconí hepatic cinnabar (" liver ore ") is disseminated in carbonaceous and manganiferous schist, and at Rio Blanco stibnite, pyrite and cinnabar occur in a quartz gangue in limestone.

Michoacán.—In the State of Michoacán, close to Tlalpujahua, there are various low-grade deposits of mercury ore which are associated with copper ores [96] They may possibly be extinct mud-volcanoes.

Mexico and Morelos.—On the Serranía de San Gaspar, which trends N.N.W. to S.S.E. and lies partly in the State of Mexico

and partly in the State of Morelos, are the old Santa Rosa mercury mines, in which deposits of cinnabar form irregular masses and veins with clay and quartz in dolomitic limestone These mines were among the first worked in New Spain, and were thrice closed by Royal Decree between 1700 and 1750. Two 20-ton Scott furnaces, in operation for 30 days in 1911, produced 200 flasks of mercury. The revolution then began in Morelos, and the mines were closed for some years. An American syndicate is reopening the old mines; the furnaces are being repaired; and a new 5-ton Scott furnace is under construction.

In 25 years, or from 1896 to 1920 inclusive, Mexico has produced 4,326 metric tons of mercury, an average of 173 metric tons per annum. The highest production was in 1898 with 353 metric tons, and the lowest in 1917 with 33 metric tons.

United States

In the United States, as pointed out by Ransome [2/1917], mercury deposits are found in the western part of the country, where the products of Tertiary and later volcanism abound, and where numerous hot springs testify to the comparatively recent age of much of the igneous activity. By far the most abundant and productive deposits are in California, Texas comes next in productivity, and is followed by Nevada, whilst Alaska, Arizona, Idaho and Oregon are usually small producers. Mercury ores also occur in Washington, Montana, Utah and Wyoming, but the output from these states has always been intermittent and, with the exception of Utah, inconsiderable.

The grade of mercury ore in the United States being low (averaging about 0·5% mercury), the fall in the price of the metal and the rise in the cost of mining and treatment since 1918 have very adversely affected the United States' production. In 1921 it amounted only to 6,339 flasks, or less than half that of 1920, and only about one-fourth of the average annual production from 1912 to 1919 inclusive; it is the smallest output on record since 1850. Of this output, Texas is credited with 3,144 flasks, California with 3,094, Nevada with 100, and Idaho with one only. There has been no pro-

duction from Alaska and Arizona since 1917 , there was non from Idaho in 1919 and 1920, and none from Oregon in 1921

Alaska

Although the occurrence of mercury ore in the Kuskokwin River region of Alaska was noted in 1883, the only deposi upon which any development work has been done is tha known as the Parks Prospect, which was discovered in 1906 on the north bank of the river, 15 miles above Georgetown The ore occurs as cinnabar, associated with stibnite, quartz siderite or ferruginous dolomite, in shattered and brecciated Cretaceous shale, related to highly-altered igneous rock (andesitic and granitic). The stibnite and cinnabar wer deposited almost contemporaneously, as each encloses, or i enclosed by, the other [107]. Owing to the inaccessibility of the region, development work has been retarded, but operations were being carried on in 1919, when some retorts wer erected. The mercury produced was sold to placer mine locally and in the Seward Peninsula.

About 100 miles downstream, and 5 miles below Kolmakof is another deposit in which lenses and veinlets of cinnabar bearing quartz occur in arkosic sandstone, closely associated with a sill of altered hornblende-andesite. The arkose is interbedded with shale, but the cinnabar is practically confined to one bed of the former. No development work has yet been done on this prospect [108].

It is stated that a dredge operating on a gold placer deposit on Candle Creek, also in the Kuskokwim region, obtains annually from its sluice boxes several hundred pounds of cinnabar, which is associated with quartz [2/1919].

Cinnabar, associated with stibnite and quartz, has been found in the residual placer material in the areas of intrusive rock near Iditarod [107], and in 1919 a small cinnabar-bearing lode was discovered in the same region.

Cinnabar is found in quantity in the concentrate from placer mining on Daniel's Creek, about 60 miles from Nome, Seward Peninsula : the mineral appears to occur at a contact of schist and limestone. It is also abundant in the placers of Iron Creek in the same district [109].

Arizona

Mercury deposits occur in Gila and Maricopa counties in a strip of country about 6 miles long, that extends north-eastward across the Mazatzal Range, in the vicinity of Pine Butte, 11 miles south of North Peak, Arizona. In the S W. part of the mercury belt, three approximately parallel lodes are recognized. These are from 300 to 500 ft. apart. Nearly all development work has been done on the middle or Pack-over lode, which appears to be the longest and most mineralized. The lodes, which conform to the lamination of the pre-Cambrian schist in which they lie, consist of veinlets, films, and specks of cinnabar in schist, without definite walls, as a rule. The gangue consists of calcite, a ferruginous carbonate, quartz and some barytes. Pyrite, chalcopyrite (rare) and hæmatite are sometimes associated with the cinnabar. Most of the veinlets or stringers lie in the cleavage-planes of the schist, and range from mere films to veins 6 in. in thickness. In some places stringers cut across the cleavage-planes. In one place the schist for a width of at least 75 ft. contains little veinlets of cinnabar and gangue. From tests made it is estimated that 9 ft. of the above width might assay 0·5 to 1% mercury. The lodes have yielded some metal, but there has been no continuous production [110].

In the Winifred mining district, Maricopa Co., a cinnabar-bearing belt, about 3 miles wide, trends N.N.E. across the southern part of the Phœnix Mts., about 10 miles N.E. of Phœnix. The rocks are metamorphosed sediments of pre-Cambrian age. The mineralized shear-zones contain specks, veinlets, crystals, etc. of cinnabar and metacinnabar in a gangue of quartz, calcite, hæmatite and limonite. The ore minerals appear to have been formed through impregnation, and also through metasomatic replacement of the schist. The deposits, which have been partially developed, are similar in character to those of the Mazatzal Range, but are of greater accessibility [111].

In 1917 Arizona produced 40 flasks of mercury, 38 of which came from the Sunflower district in the Mazatzal Range, and

2 from the Phœnix Mts. [2/1917]. There has been no production since then.

California

From 1850 to 1921 inclusive, California—by far the premier mercury state—produced 2,261,181 flasks, or 76,293 metric tons of mercury, which is at the rate of 1,068 metric tons per annum for 72 years, this is equal to, if not rather more than, the average annual production of the great Almaden mine of Spain during the last 50 years. In 1921, however, the output of Texas exceeded that of California. About 80% of the United States' output has come from ten mines—New Almaden is by far the principal of these, with a total production from 1850 to 1917 of 1,021,183 flasks, New Idria ranks second, with a total production from 1858 to 1917 of 306,475 flasks; and Oat Hill, third, with a total output from 1876 to 1917 of 152,066 flasks.

The principal Californian mercury deposits, which occur in the Coastal Ranges, within a belt 400 miles long, and having a maximum width of 75 miles, are mainly in the Franciscan (Jurassic ?) formation, with some also in the adjacent Knoxville (Lower Cretaceous). The Franciscan group lies upon the eroded surface of a complex of plutonic and metamorphic rocks, and is composed chiefly of sandstones, radiolarian chert, foraminiferal limestone and lavas, associated with which are intrusive masses of spheroidal basalt and serpentinized peridotite. The Shasta series (Lower Cretaceous) rests unconformably upon the Franciscan group, and upon the former lies the Chico formation (Upper Cretaceous). The Cretaceous rocks, as well as the Eocene (Tertiary), which succeed the Chico, are composed chiefly of shales and sandstones. Oligocene, Miocene, Pliocene, Pleistocene and Quaternary formations are also represented (A. C. Lawson, *quoted by* [17]).

G. F. Becker [81] distinguishes three principal periods of igneous intrusion to which the ore deposition is genetically related: (1) Pre-Pliocene, in which large masses of andesite were ejected; (2) a later andesitic eruption, near the close of the Pliocene; and (3) basalt eruptions belonging to the Quaternary and more recent periods.

In 1919 the principal counties producing mercury were, in

order of importance · San Benito (New Idria mine), Santa Clara; Sonoma; San Luis Obispo, Napa, and Lake.

Kern County.—The deposit in which the Cuddeback mine, Kern Co., has been developed is a recent discovery, and lies outside the recognized mercury belt of California. It consists of a cinnabar-bearing rhyolite dyke in granite or granodiorite The ore-bodies, of irregular form, occur in the dyke near small fissures, usually parallel with the dyke walls. The typical ore is rather soft, altered, chalky rhyolite, coloured pink by finely disseminated cinnabar. Cinnabar is stated also to be present as veinlets or seams ⅛ in. thick Early in 1918 the workings were only 30 ft. below surface [2/1917]. There was probably a small production during the first half of 1920, but "inquiries at the end of the year failed to elicit any response" [2/1920].

Lake County.—From 1837 to 1919 inclusive, Lake Co. produced 252,923 flasks of mercury. In the Abbot mine the deposit occurs in serpentine near its contact with shale, and only exceptionally in the latter rock. The filling consists of cinnabar disseminated through crushed "opaline" in seams and pockets, and partly as a coating. The ore-zones contain a large amount of pyrite with very little gouge (flucan) on the walls [112]. The mine was closed down in 1917.

The Great Western mine from 1873 to 1909 produced 98,316 flasks; it was afterwards closed down. The ore-body strikes N.W. and dips 70° S.W. The foot-wall is a hard sedimentary rock altered by silicification; the hanging-wall is serpentine. The ledge matter is formed by a series of thin beds of chert with bedding-planes parallel to the strike of the ledge, and interstratified with clay seams. There is a black *alta* or clay selvage on the hanging-wall. The cinnabar is generally in seams, and coating the fractures of the chert, but richer spots are disseminated through the chert itself, associated with pyrite [17]. The cinnabar is also associated with bituminous matter [28/p. 455].

The famous Sulphur Bank mine, formerly worked for sulphur, has produced 92,400 flasks of mercury. Solfataric springs occur here. The gases escaping from the waters are carbonic acid, sulphuretted hydrogen, sulphur dioxide and

marsh gas. The waters contain carbonates, borates and chlorides of sodium, potassium and ammonium. Alkaline sulphides are also present. According to G. F. Becker [81] cinnabar is found in the lower portion of the zone of oxidation in more or less decomposed basalt, in the underlying recent lake bottom, and in the Knoxville shales and sandstones. The cinnabar is associated with silica, in part crystalline and in part amorphous. In the lava it appears in small seams following the original cracks between the blocks or the concentric surfaces of the decomposed masses. In the lake deposits below the basalts cinnabar is found as impregnations or irregular seams. The ore is associated with sulphur, opal, quartz, pyrite, and to a small extent with calcite. Becker says that, except for the solfataric springs, the underground mine at Sulphur Bank resembles the other principal mercury mines of California.

In 1917 the dumps of the old Sulphur Bank mine—estimated at 800,000 tons—were being handled with a steam shovel, the ore being crushed and concentrated. These dumps yielded the largest mercury output of the county in 1918, but there was practically no production in 1919 [2/1919].

Other producing mines in Lake Co. are the St. John's and the Helen.

Napa County.—From 1863 to 1919 Napa Co. produced 338,951 flasks of mercury.

In the Corona mine there is a zone of black chert rocks lying between a sandstone foot-wall and probably a serpentine hanging-wall, striking N. 45° W. and 10 to 15 ft. in thickness. The cinnabar is in fissures running through the opaline rock [112].

In the Knoxville mine there are three parallel veins in a mineralized zone enclosed in serpentine. The cinnabar is associated with pyrite and quartz, and is often found in columnar and circular forms. The gangue is a black opal, in part resembling obsidian. Metacinnabar is also an associate. Knoxvillite and redingtonite—complex hydrous sulphates of chromium, iron and aluminium—were first identified from this mine [17/p. 83]. According to Becker redingtonite has resulted from the action of solfataric gases of chromite.

In the Manhattan mine the ore deposits are all contiguous to basalt. Occasionally a little pyrite, sulphur and stibnite are associated with cinnabar.

The above three mines have been idle since 1917.

At the Oat Hill (Napa Consolidated) mine cinnabar occurs as impregnations in soft, light-grey sandstone. A little barytes is found at Oat Hill, as well as at New Almaden [28/p. 455]. From 1876 to 1917 the mine produced 152,566 flasks. The mine was closed in 1920.

The Aetna mine, the leading producer of Napa Co. in 1918, was closed in 1919.

San Benito County.—From 1865 to 1919 San Benito Co produced 334,259 flasks, mainly from the New Idria mine, which in recent years was responsible for nearly half the production of the State, and was the largest producer in the United States.

In the New Idria mine the formation consists of Franciscan metamorphic sandstone and shale, some distance from the contact of a large serpentine area. Some of the shale is indurated so that it resembles slate. The hanging-wall is marked by a black gouge (flucan) or *alta*. The main ore-zone is roughly elliptical in shape in the upper levels, narrowing, lengthening eastward, and curving towards a crescent shape in the lower levels. The strike is N.W., and the general dip S.E. 60° to 65°. On the No. 5 level the deposit is 235 ft. wide between walls, and 800 ft. long. On the No. 10 level (1,060 ft. vertical) it averages 120 ft. in width, and is 1,200 ft. long. The ore occurs as veins, cross-veins, stock-works and impregnations. The main associate is pyrite (not abundant); the gangue consists of quartz, calcite and gypsum, with bituminous matter. A considerable amount of meta-cinnabar was found in two veins, which intersect the main zone. The San Carlos mine (belonging to the same company) is nearer the serpentine contact. From the north end of the New Idria to the south end of the San Carlos the proved area has a length of 2½ miles, and there are 15 to 20 miles of underground development [17/p. 112]. The mine was idle in the latter part of 1920 and in 1921. The reduction plant was destroyed by fire in 1920.

San Luis Obispo County.—Cinnabar from the Sierra Santa Lucia had been used by the Indians for pigment for generations before the miner appeared. The first location was in 1862. From 1876 to 1919 the county of San Luis Obispo produced about 49,800 flasks.

In the Cambria mine cinnabar occurs in an intensely-brecciated serpentine, as small stringers in a siliceous gangue, and as a coating on the serpentine fragments. One mineralized zone has an average width of 20 ft. , prominent streaks of dark clay selvage occur throughout and in places form an *alta*. Both walls are serpentine. The mine was closed in 1917.

The Klau mine, after producing 14,213 flasks of mercury, was closed in 1916. It was reopened in 1919. There are two main ledges, striking N 50° W. and dipping N.E. The more south-westerly ledge has serpentine on the foot-wall, and a slightly metamorphosed sandstone on the hanging-wall, which forms the foot-wall of the second ledge The filling of the first ledge consists of loose, coarsely-granular quartz, carrying cinnabar and pyrite. In the loose quartz are boulders of very hard chalcedonic quartz, and of a laminated, somewhat calcareous material, which sometimes contains cinnabar and pyrite. The second ledge has formed what appears to be a brecciated zone of country-rock, of quartzose character with some clay in it, probably an attrition product. This ore contains much pyrite and some free sulphur.

The Oceanic mine at the end of 1917 had produced 23,251 flasks of mercury. It was the only producer in the county in 1918, with 1,460 flasks. The ore is remarkably uniform in value. The mineral, cinnabar, is very finely disseminated in a fine-grained sandstone, which contains calcite, and with which petroleum is associated. The hanging-wall is serpentine and the foot-wall, shale. On the S.W. side, and more or less parallel to the ore-body, is a mass of igneous rock of the diorite-gabbro series [17/p. 142]. A new ore-body with 0·3% mercury was discovered in 1919, east of all previous workings, at a depth of 550 ft.

Santa Clara County.—The New Almaden group of mines [17], [81], [113] was discovered in Santa Clara Co. by tw

Mexicans in 1824, but the ore was not recognized as cinnabar until 1845. The large output of mercury from the mine has already been mentioned. Altogether 18 shafts have been sunk, and there are nearly 100 miles of underground workings, a large proportion of which have, of course, caved in. The greatest depth in 1917 was 2,450 ft. below the top of Mine Hill (1,600 ft. altitude), so it is the deepest and most extensive mercury mine in the world. The part of the mine below the 800 ft. level was abandoned some years ago. The grade of the ore compared with that of the Almaden mine, Spain, is very low, varying from 0·2 to 1% mercury only.

In recent years the principal producing section of the New Almaden mines has been El Senador, about 4 miles N.W. of Mine Hill, which was the chief producer of the 7 mines reporting production in 1921 in California.

In the vicinity of the New Almaden mines serpentine is associated with metamorphic sandstones and jaspilites of the Franciscan series. The general trend is N.W., and the outcrops can be traced for 3½ miles The ores are wholly in serpentine (F. L. Ransome). There are two main fissures, and the great ore-bodies are distributed along these, passing irregularly into the walls. The wedge between the fissures also contains ore-bodies. The shattered masses of country rock, in which the ore-bodies occur, are generally rather hard and siliceous, and, according to Forstner [112], " are traversed by a network of seams of quartz and dolomite, showing repeated fissuring and filling containing some inclusions of serpentine, the cinnabar forming principally in connection with the seams." The general character of the vein-filling indicates that, as in most of these mercury deposits of the state, the deposition of the cinnabar has been associated with the process of silicification, which characterizes the alteration of the rocks of the Franciscan series [112]. There is a dyke of rhyolite, nearly parallel to the line connecting the New Almaden and Guadalupe mines, of post-Miocene and probably of post-Pliocene age. The main fissure was formed at the time of the rhyolite eruption, and to the latter Becker [81] ascribes the genesis of the ore. In this connection it may be mentioned that cinnabar occurs finely disseminated in a rhyolite dyke in the Cuddeback Cinna-

bar mine, Kern Co. (*see* p. 71) [17/pp. 47–8], and also in rhyolite in Nevada (*see* p. 80).

The cinnabar (sometimes with a little native mercury) is associated with pyrite, marcasite and crystals of chalcopyrite (rare). A notable feature of El Senador mine is the presence of fairly abundant stibnite in fine needles [99/1917]. The gangue consists of quartz, calcite, dolomite (more prevalent than in most mercury mines) and magnesite. There are present as well a small amount of chalcedony or opal, usually black (less abundant than in the northern mines), and masses of bituminous matter.

Becker could find no evidence of substitution. The ore occurs only close to evidences of faulting, *e.g.* where there are layers of attrition products, so-called clays, full of slickensides and fragments of rock more or less rounded by attrition. Where these clays form on the hanging-side (*alta*) they are impermeable to solutions, and the ore usually forms on their lower sides. Although there are sometimes clean-cut fissures filled with ore, the commonest type is stockworks, or irregular bodies of broken rock into which solutions of cinnabar and gangue minerals have filtered, cementing the fragments together with ores. The deposits as a whole have a vein-like character, and belong to the chambered-vein class (Becker).

Solano County.—The mercury production of Solano Co. from 1873 to 1918 amounted to 17,116 flasks.

The St. John's mine was discovered in 1852; production of mercury began in 1873, and to the end of 1917 the total output amounted to 16,453 flasks. There was also some production in 1918 and 1919. The ore occurs in the Knoxville formation (Lower Cretaceous), consisting of soft shales with lenses of limestone and thin beds of sandstone. The sediments have been intruded by peridodite, altered to serpentine. There are a few short blunt dykes of meta-andesite which have been injected into the shales. Near the contact the shales are altered to a hard, black, siliceous shaly material. The ore-bodies have formed invariably in the dykes or in the hardened shale along their borders, or in the fault-breccias near them.

The cinnabar is associated with pyrite or marcasite; the

matrix is quartz and calcite. A thick dark-brown mineral oil is found in joints and fissures in and near the ore-bodies. The mine is 650 ft. in depth (Oscar H. Hershey, *quoted in* [17/p. 173]).

Sonoma County.—The mercury production of Sonoma Co from 1873 to 1919 amounted to 69,063 flasks.

The Great Eastern and Mount Jackson mines from 1875 to 1917 produced 42,092 flasks of mercury. Serpentine forms the hanging-wall, and sandstone the foot-wall. The ore-shoot is enclosed within a ledge of opalized rock, probably mostly serpentine originally. Becker [81] considers that the silicification preceded the deposition of the ore, though somewhat closely connected with it. Pyrite occasionally occurs with the cinnabar. The ledge filling is characterized by numerous cross-fissures, at a flat angle, filled with quartz stringers like the " ladder veins " described by Lindgren [59/p. 146]. The ore forms principally in relatively softer zones in this material. Accompanying the ore, frequently in stringers parallel to the quartz partings, is a brittle black bitumen (grahamite ?) which is usually associated with good ore [17/p. 189].

The Rattlesnake mine is peculiar as native mercury only occurred in a black brecciated mass and gouge with no definite walls. An oily bitumen was associated with the native mercury. The mine was worked on a small scale in 1917.

In the Socrates mine the ore occurs in a ledge of soft opaline rocks, which are considerably fractured A " horse " of black serpentine runs through the middle of the ledge matter. In the upper levels the foot-wall consists of sandstone and shale, and on the hanging-wall side there is a thick layer of black gouge. In the lowest level the black gouge is on the foot-wall, and the hanging-wall is a hard serpentine. In the upper levels the mercury was nearly all in the native state, but a considerable proportion of cinnabar is showing in the lowest level, either disseminated, or as veinlets, with some pyrites or marcasite and calcite. Chlorite, an end product of the alteration of serpentine, is abundantly present. Tiemannite, a selenide of mercury, has been found in the mine [17/p. 193].

There was a small production in 1918, but operations were suspended throughout the county in 1919.

Trinity County.—The mercury production of Trinity Co. from 1875 to 1917 was 31,166 flasks Of this quantity the Altoona mine, near Castella, is responsible for 29,000 flasks. The ore appears to be a contact deposit between serpentine (foot-wall) and porphyry There are four veins; three of these come together in the lowest levels, forming a mineralized zone 400 ft. long and from 4 to 50 ft. wide [17/p 201].

Yolo County.—The Reed mine in Yolo Co. is close to the contact of serpentine and an unaltered fossiliferous rock. The ore-bodies occur in opaline material. The principal ore is metacinnabar which is associated with pyrite in a quartzose gangue. Some bitumen is present. The mine is 300 ft. deep [17/p. 205].

There was a small production from the January mine in 1917 and 1918, but all production in the county ceased at the end of 1918.

Idaho

Valley County.—The Yellow Pine cinnabar district of Idaho is in Valley Co., about 50 miles N.E. of Cascade, and covers an area of about 1 sq. mile. The deposits are in limestones, quartzites and some schists (probably Palæozoic), and, for the most part, very near the contact between the two former rocks. The sedimentary rocks, which strike N.-W. and are nearly vertical, are surrounded by a great body of granodiorite —their metamorphism being probably due to this intrusion. The ore-bodies appear to be irregular lenses or chimneys of silicification in the limestone, and the ore is in part chalcedonic silica and in part the friable marble that adjoins the silica bodies. The cinnabar is associated with some pyrite. The deposits appear to have been formed by replacement of the marble, and antimony deposits in the granodiorite immediately to the south and west, carry a little cinnabar and are probably related deposits. Some of the claims have been developed to a certain extent, but the economic value of the deposits has not yet been ascertained. Good ore from one claim gave a furnace yield of 2% mercury [114]. The small productions of Idaho of 5 and 22 flasks in 1917 and 1918 respectively, came chiefly from the Fern mine. There was

no production in 1919 and 1920. During 1921 the United Mercury Mines Co. acquired over 100 claims in the Yellow Pine district, and from development work produced a single flask of mercury. This was the only production in the state.

Nevada

Nevada contains many widely scattered deposits of mercury ore, a few of which have been fairly productive for short periods.

Elko County.—At Ivanhoe Springs, Elko Co., cinnabar occurs as irregular stringers and as streaky disseminations in a much-altered, glassy rhyolite flow breccia.

Humboldt County.—At Goldbanks, Humboldt Co., an occurrence of cinnabar ore is very similar to that at Ivanhoe Springs, Elko Co. Near Antelope Springs, in the same county, cinnabar is found superficially dispersed through shattered limestone, conglomerate or breccia

Mineral and Esmeralda Counties.—There has been a small production from two deposits near Mina, where cinnabar occurs superficially in shale with oxidized lead ores. At Mt. Montgomery cinnabar occurs in a glassy, brittle variety of rhyolite.

According to Adolph Knopf [115], a belt of cinnabar deposits trends N.E. for 2 miles in the heart of the Pilot Mts., 8 miles S. of E. of Mina. The principal locality is now known as Cinnabar Mountain. The cinnabar occurs in fracture zones in limestone (probably Palæozoic), disseminated in thin veinlets of calcite or dolomite, and also as replacement of the wall-rock. In one place, cinnabar is associated with stibnite, but there is a marked absence of pyrite and marcasite. North of Cinnabar Mt., the cinnabar is in brecciated chert in a gangue of barytes, and, farther north, in greywacke in a siliceous gangue.

Nye County.—There is a mercury-bearing area on the east slope of Bare Mt., in the Fluorine Mining district, about 6 miles east of Beatly, Nye Co. The country rock is dolomite (Silurian) cut by a number of porphyry dykes. In the dolomite are small masses, erratically distributed, of opal or of cryptocrystalline silica, carrying cinnabar, but no other metallic sulphides.

The mercury-bearing area north of Meikeljohn Mt. is underlaid by rhyolite flows and tuffs (probably early Miocene). The deposits consist of masses of opal and alunite, with cinnabar sporadically disseminated in them but without association with other metallic sulphides. The opalized belts in the rhyolite extend for 1,000 ft. or more, and attain widths of as much as 200 ft. Alunite has not hitherto been recorded in association with mercury ores, but it is of interest to know that the mineral occurs in considerable quantity in the sulphur deposits resulting from the solfataric alteration of rhyolite tuff at Rabbit Hot Springs, Nevada, and these deposits contain traces of cinnabar.

A few flasks only of mercury have been produced from these prospects.

The Mercury mine, near Ione, Nye Co., has in recent years been the chief producer of the state. According to Ransome, the ore occurs in Tertiary rhyolite, which has been faulted down against greenstones (probably Carboniferous). Cinnabar occurs near, and partly within, a rock of coarse agglomerate containing abundant boulders and angular fragments of soft altered rhyolite, the largest 4 or 5 ft. in diameter, together with boulders and fragments of the older rocks. This mass of agglomerate probably fills a hole blown through the older rocks by a volcanic explosion at the time of the Tertiary rhyolitic eruption of the region. The chalky rhyolite boulders of the agglomerate are impregnated with cinnabar, which also occurs in crevices in shattered limestone, and in shale in the limestone.

From 1910 to 1919, inclusive, Nevada produced 13,746 flasks of mercury. Since 1919 production has decreased considerably, amounting to only 79 and 100 flasks in 1920 and 1921 respectively.

Oregon

Cinnabar is widely distributed through Oregon, but the producing mines have hitherto been few in number.

Douglas County.—In Douglas Co. cinnabar occurs in soft bleached and much-altered andesitic rock, which is in contact

with shale along its eastern boundary, due to a westerly dipping fault. The deposit is no longer being worked.

Jackson County.—The Meadows mining district is the most important one of Jackson Co. The War Eagle Mining Co. erected a 25-ton Scott furnace on the Rainier mine in 1920, but no production was recorded in 1921 [19/1921].

A large body of cinnabar ore occurs 12 miles north of Gold Hill, in that district. The mineralized zone, from 100 to 200 ft. wide, is along a granite-sandstone contact, where the granite is in part pegmatitic The ore contains cinnabar, native mercury, pyrite, gold, zinc, silver and a heavy black mineral resembling metacinnabar. Samples taken from several adits assayed from $5 to $6 in value of gold, and 5 oz. silver per ton; 2·5% zinc, and 1% mercury. Rich cinnabar ore appears all through the mass in the form of seams, from 1 to 20 in. in thickness, and in kidneys. The mine is equipped with a mercury furnace with 12 pipes, and has been a producer since 1916. There was a very small production in 1919. Considerable development work is being carried on, and much rich ore has been uncovered in the War Eagle Group adjoining [116]

According to A. E. Kellogg [117], cinnabar occurs as a breccia and stockwork structure along an open fissure, averaging 5 ft. in thickness, in quartzite, having bituminous shale underlying it The quartzite is 400 ft. wide and 3,000 ft. long. A dyke-like intrusion of Tertiary or post-Tertiary age, striking N.–S., cuts the quartzite east of the ore, and is no doubt connected genetically with it. There is usually a gouge or selvage on both walls of the fissure. The cinnabar is found between fragments of quartzite, and, by replacement, in quartz associated with pyrite. The grade of the ore is erratic, being in proportion to the amount of quartz-breccia present. Exposures on the surface indicate shoots along the fissure for over 900 ft. in length. In a drive, at a vertical depth from surface of 272 ft., there was low-grade ore for 55 ft.; then the ore was in bunches for 60 ft. in length. The deposit was from 3·3 to 6·2 ft. wide, the ore assaying from 1·75 to 9·1% mercury; 1,500 tons treated produced 42,375 lb. mercury.

There is a 35-ton Scott furnace at the War Eagle mine.

The working cost, including mining, development, reductior management and general, is given as $10·44 per ton.

Lane County.—At the Black Butte mine in Lane Co cinnabar, with a little native mercury, occurs in a fissur zone in altered andesite and andesite-breccia, being a light coloured, rather soft rock, with stringers of hard, brown materia formed by the segregation of iron oxide along cracks Th cinnabar occurs as stringers, rarely over 1 in. thick, and sma specks through the altered rock. Marcasite and pyrite ar in places associated with the cinnabar, and, occasionally masses of black, fibrous, carbonaceous material, probabl carbonized wood, and irregular stringers of stibnite are foun in the workings. The main stope, 180 ft. long and 15 ft wide, has been carried to a depth of about 400 ft. [2/1917] The ore contains about 0·25% mercury, and the reserves i 1917 were estimated at 150,000 tons. This mine, which wa the leading producer, was closed during 1919 [2/1919].

From 1916 to 1920, inclusive, Oregon produced 1,85 flasks of mercury; in 1921 there was no production.

Texas

Brewster County.—The mercury deposits of Texas are al in Brewster Co., and were discovered in 1894. The tota production of the county from 1899 to 1919 amounted t about 89,670 flasks.

The principal cinnabar-bearing zone is 15 miles lon and about 2 miles wide. The richest ore-bodies are under o near California Hill (Terlingua district), where the Lowe Cretaceous limestone is penetrated by two dykes of andesite and is covered by more or less impervious shale. The cinnaba occurs in fissure veins or mineralized lines of faulting, strikin N.E.–S.W. and approximately vertical. As shown b Udden, many of the deposits are found at the crests of anti clines [118], [119]. The lodes are of two kinds: (1) Friction breccia lodes and (2) calcite lodes. The former consist o limestone and shale cemented by calcite and gypsum, wit which iron oxides (secondary from pyrite) are associated Many of the smaller lodes pinch out in depth. The deepes working in 1906 was 300 ft., but a churn drill found lod

material at a depth of 446 ft. The strongest calcite lode strikes N. 75° E., is from 2 to 10 ft. in thickness, and can be traced for over a mile. The calcite in it has a banded structure. At many points the lode is filled with ground material and irregular masses of shale, with which cinnabar is associated and which yield on an average about 1% mercury. A large amount of the white calcite contains cinnabar, but, as a rule, it is low-grade (0·25% mercury). The Tierra lode can be traced for 2,500 ft., and consists of red shaly material and calcite. Surface waters have formed open fissures and caves in the limestone, which are now filled with detritus. The main open fissure was formed along the middle line of the lode, and is from a fraction of an inch to several feet in width. It has, to a greater or less extent, been filled with loose material washed from above. It has been followed for 460 ft. in length and 150 ft. in depth. Remnants of the original ore-body occur alongside the secondary ore. Bones and teeth of a ground sloth and of a horse (both extinct) have been found embedded in the detritus at the 100 and 150-foot levels. In some of the caves the oxychlorides, terlinguaite, eglestonite and montroydite, native mercury, and a little calomel are associated with the cinnabar. Many tons of the oxychlorides have been sent to the reduction works [120] The grade of ore mined in the Terlingua district varies from 0·5 to 4% mercury. The furnaces are of the Scott type, and wood is the fuel used [121/p. 160].

In the Upper Cretaceous formation the ore occurs in shales and sandstones, as well as in trachyte, intrusive in the shales. The joints of the trachyte are filled with cinnabar and calcite, and cinnabar impregnates the whole mass and is associated with pyrite. The shales and sandstones have been cut by fractures along which the cinnabar has been deposited. The fissures strike from N. 63° E. to N. 75° E., and are nearly vertical. The mine belonging to the Colquitt-Tigner Mining Co. has a vertical pipe of oval or circular shape, about 75 ft. in diameter, and filled with detritus, consisting above of fine grey comminuted material, and below of angular fragments of shale and sandstone, cemented by calcite and a bituminous substance. There are traces of cinnabar in the pipe [120].

The Chisos mine, of the Terlingua district, Texas, has for several years been the second most productive mercury mine in the United States, New Idria in California coming first. The ore is of somewhat higher grade than that of California.

The Chisos ore-bodies lie along a strong curved fault-zone with a general E.–W. trend, which has been proved for a length of 2,500 ft. and a depth of 750 ft. Above the 550-foot level, the ore was in the Eagle Ford shales (Upper Cretaceous), but below that it was found chiefly in the Buda limestone (Lower Cretaceous). On the 700-foot level there was some ore in the Edwards limestone (also Lower Cretaceous), a limestone which has supplied most of the ore of the Mariposa and other mines west of the Chisos. From the surface to the 600-foot level the ore-bodies occurred at intervals nearly all along the explored portion of the fault-zone, but below this level the rich ore was found in the form of a chimney, from 75 to 100 ft. in diameter, extending down to the 750-foot level. The ore-chimney is in a mass of shattered Buda limestone, which probably has been faulted down into the Del Rio clay-shale, perhaps as a consequence of the collapse of a solution chamber in the massive Edwards limestone. The ore in this dropped mass is a chaotic breccia consisting chiefly of fragments of Buda limestone with cinnabar, native mercury, free sulphur and marcasite or pyrite, and possibly other minerals, as an interstitial filling, and as a replacement of some of the smaller lime fragments [2/1917].

From 1899 to 1920, inclusive, Texas has produced 93,271 flasks of mercury. The highest output was 10,791 flasks in 1917. Since then production has decreased at a rapid rate, but nevertheless, in 1921, the output of mercury in Texas exceeded that of California, being 3,144 flasks.

Utah

At Mercur, Tooele Co., Utah, a deposit of earthy cinnabar with a siliceous gangue was mined from 1903 to 1907, and yielded a considerable amount of mercury. According to J. M. Boutwell [122], the cinnabar occurred in bands in an altered cherty limestone adjacent to a fracture zone and a dyke. The cinnabar-bearing limestone formed a lenticular

shoot, 50 ft. along the strike, 140 ft. on the dip and 10 ft. in thickness, which was coincident with the bedding of the limestone along the middle and major portion of its dip, but at its upper edge it bent round upward and cut abruptly across the bedding, while, at its lower edge, on approaching the dyke and fracture on its dip, it dropped sharply down across the bedding, pinching out at both its upper and lower terminations to thin edges.

The winning of the deposit was incidental to the mining of gold ores. The yield of mercury was 6% on an average, and 80% in picked samples.

At one time some mercury was recovered from tiemannite (HgSe) and onofrite (HgS,Se). These rare mercury-selenide minerals occurred near Marysvale, in Southern Utah, in a fissure-filling in limestone, in a district of volcanism, with rhyolitic and andesitic flows [59/pp. 462 and 464].

In 1905 the output of mercury from Utah amounted to 1,133 flasks [123].

Washington

Mercury ores have been found in the State of Washington, but so far production has been inconsiderable [3/p. 341].

The production of mercury in the United States received a great stimulus from the high prices fixed during the war, and many virgin and low-grade deposits were worked, which are scarcely likely to be remunerative at the prices now prevailing. As already explained, the drop in the price of mercury and the rise in mining and reduction costs since 1918, have been followed by a great decrease in the United States output of mercury. European exchange has also been unfavourable to mercury mining in the United States [2/1920]. The Almaden deposits of Spain, being of high grade, have not been affected by the two first factors to the same extent, nevertheless, efforts are being made by the Government officials of Spain to use modern and economical methods both in mining and reduction, which is bound, in the near future, still further to affect adversely the United States' production.

At present there is an import duty of 10% *ad valorem* in the United States, but a modification of this is probable in the near future

The production of mercury in flasks of 75 lb. in the United States for recent years is as follows

	California.	Texas	Nevada	Oregon	Arizona, Idaho and Washington	Total
1914 . .	11,303	3,156 (a)	2,089	—	—	16,548
1915 . .	14,283	4,423 (b)	2,327	(c)	—	21,033
1916 . .	21,045	6,306	2,198	378	5 (d)	29,932
1917 . .	23,938	10,791	997	313	120 (e)	36,159
1918 . .	22,664	8,451	1,044	702	22 (f)	32,883
1919 . .	15,205	5,019	756	435	—	21,415
1920 . .	9,849	3,436	83	24	—	13,392
1921 . .	3,055	3,183	100	—	1 (f)	6,339

(a) Including Arizona.
(b) Including Arizona and Oregon
(c) Included in Texas.
(d) Arizona only.
(e) Arizona 40, Washington 75, and Idaho 5 flasks
(f) Idaho only.

SOUTH AMERICA

BRAZIL

Cinnabar occurs at Tres Cruzes, Ouro Preto, Brazil, disseminated in a quartzose vein in a lenticular conglomerate intercalated in the midst of schists, as well as in the schists themselves, in stratiform nests associated with iron and manganese oxides. The cinnabar is sometimes very finely disseminated in an argillaceous and bituminous mass containing petroleum, and is sometimes in thin layers or in lamellar or even compact masses. The dark bituminous ore seems to form a bed round the quartzose lode. The cinnabar-bearing quartz sometimes contains little pellets of gold, as at the New Almaden and Manzanita mines in California [28/p. 464]. Samples from this deposit have assayed from 0·88 to 4·73% mercury [19/1902, p. 543].

Cinnabar is said to occur in other parts of Minas Geraes [124/p. 194].

CHILE

In the Punitaqui gold mines in the Province of Coquimbo, Chile, in a dolerite dyke, which cuts through syenite and diorite,

are veins of cinnabar, a red powder (oxide ?), native mercury, and a tetrahedrite containing about 10% mercury, together with pyrite, chalcopyrite, hæmatite and chalcocite, the gangue being mainly hard quartz The cinnabar is principally in finely-disseminated particles in the quartz, the remainder (about 10%) is massive or in crystals.

Ores containing 0·4% mercury and upwards are being treated in retorts from 12 to 24 in. in diameter [125], [126], [2/1917].

In the same province, near Arqueros, the occurrence of native silver amalgam has long been known [127], the same mineral is found near Rosilla, Province of Atacama, and cinnabar is reported near Petorca, in the Province of Aconcagua [2/1917].

Colombia

A zone of cinnabar-bearing rocks, striking in a general N.–S. direction, can be traced, according to F. P Gamba [128], from Santa Rosa (Department of Antioquia) through Quindiú (close to the boundary between the Tolima and Cauca departments) to Miraflores, in the centre of the Department of Tolima.

The only property upon which any development work has been done is that of Quindiú, which is in the district of Bermellón (the name given to an earthy variety of cinnabar). Humboldt states that a vein of cinnabar was discovered here in 1786, and that in the alluvium near the River Bermellón, at the foot of the plateau on which the old town of Ibague was situated, rounded fragments of cinnabar were found mixed with pellets of gold. In 1886 the Colonial archives were examined by Joaquin Campuzano, who discovered a note of the year 1787 to the effect that six levels had been opened up in the Sierra de Quindiú. These were subsequently discovered on the eastern slope of the Central Cordillera of the Andes at an altitude of about 10,000 ft., were cleaned out [129], and the property was developed to a certain extent towards the end of the last century. However, the ore proved to be very low-grade, and the mine, being in an unfavourable position as regards transport, was subsequently abandoned.

7

According to E. Halse [129], the formation in which the cinnabar occurs is sedimentary, consisting of highly metamorphic schists of Palæozoic age. The schists strike, on an average, E. 30° S to W. 30° N., and dip N 39° to 43°, or towards the River Bermellón at the foot of the ridge. Hard and granular chloritic schists are succeeded by talco-chloritic and arenaceous beds, which are the cinnabar-bearing rocks of the district. These beds have seams or veins of quartz and calcite, which contain cinnabar, crystalline or compact, and pyrite running through them as veinlets or as spots. Some clay is generally present in the seams or veins With the cinnabar and pyrite some native mercury occurs, as well as tetrahedrite (very rare), galena (rare), and natural amalgam of silver and gold [128]. The surface is covered with detrital clay, derived from the decomposition of the schists, in which a certain amount of cinnabar in fine powder is irregularly distributed The thickness of this cover varies considerably. The average grade of ore contains from 0·25 to 0·5% mercury, while the hand-picked ore will yield 10% or even more [128].

There is an igneous rock at the foot of the mountain, described as a diorite-porphyry, and a porphyry dyke is said to outcrop along the top of the ridge It appears, therefore, that the cinnabar-bearing metamorphic schists occur between two intrusive dykes of igneous rock, and it is highly probable that the mercury deposit is connected genetically with one, or possibly with both, of these. The cinnabar is practically confined to the talco-chloritic and arenaceous beds, as these are more porous or have been more shattered than the harder chloritic beds [129].

Dutch Guiana

It was reported some years ago that a discovery of rich mercury ore had been made in a creek bed near Bonidoro in the Maroni district in the Dutch Colony of Surinam. It was later reported that a lode had been traced for 9 miles, and 20 ft. of rich ore had been disclosed in a trial pit 30 ft. deep [124/p. 426]. No recent information is available, but apparently the deposit has not yet been commercially exploited.

Ecuador

In the Cretaceous sandstones of the Cerro de Huaizhun, near San Marcos, near Azogues, Ecuador, are the extended workings of an ancient mine. Although no ore has been left in the mine, native mercury has been found in the neighbouring soil.

Native mercury, in insignificant amounts, has been found in alluvial deposits near Guayaquil and Pascuales; in the auriferous sands of Esmeraldas, in parts of the eastern range of the Valley of Cuenca, and in the Collay region. Cinnabar has been found near Riobamba [124/p. 407].

Peru

It is said that cinnabar was used by the ancient Peruvians as a colouring matter. Mercury deposits were formerly worked on a large scale in the departments of Huánuco and Huancavelica.

Huancavelica.—The Santa Bárbara mine [125], [130 to 133], of the Department of Huancavelica, has a famous history. It dates from 1566, and in or about 1570 it was bought by the Spanish Crown for 250,000 ducats (about £117,000), the workings at that time being 220 ft. long, 111 ft. wide, and 445 ft. in depth. According to Ulloa the mine was worked to a total depth of 1,404 ft. It was exploited in a most irregular manner, and extensive caving of the workings has occurred from time to time. One of these cavings has an area of 4,000 sq yd. and is from 100 to 200 ft in depth at surface.

In the following table the estimated production of the Santa Bárbara mine is shown from 1571 to 1903. It will be seen that its most flourishing period was from the latter part of the sixteenth to nearly the end of the eighteenth century [133/p. 42].

Period	Total Mercury produced Quintals	Average Annual Production in Tons (metric)	Average Annual Production in Flasks of 75 lb.
1571–1789 . .	1,040,469	219	6,424
1790–1843 . .	65,766	55	1,630
1844–1903 . .	10,000	7·6	225

According to Umlauff [133], the formation consists of sandstone, limestone and schist, of Cretaceous age, and conglomerate, which is said to be post-Cretaceous. Here and there in the sandstone and conglomerate are inclusions of Tertiary andesite. The eruptive rocks in the vicinity are porphyrite and basalt. The deposits are irregular, following the general trend—N. 30° to S. 30° E.—of the sandstone and conglomerate. The porous sandstone is the principal cinnabar-bearing rock. The ore exists in it in threads perpendicular to the stratification, in isolated grains and in thin masses. In the limestone the cinnabar is apt to follow the joint-planes, to form lenticular masses, to fill cavities and to form stockworks therein. The cinnabar is associated with pyrite, arsenopyrite and realgar. The usual gangue is calcite, but it may be quartz or barytes. Galena and blende are sometimes present. Some native mercury (secondary) also occurs. The rock is frequently impregnated with bituminous matter. This deposit is, in many respects, analagous to that of Almaden, Spain, and is probably of very similar origin.

The ore formerly mined at Santa Bárbara was no doubt of high grade containing probably over 5% mercury. Samples taken by Umlauff from all the principal workings gave 2%. He estimated the dumps at 150,000 tons and to average 0·10% mercury.

At Almaden and Idria the mercury content is found to increase with depth down to a certain horizon, and it is quite possible that the same thing may happen at Huancavelica. A deep adit was started by Ulloa many years ago, 2,133 ft. below the highest ground, but was only driven 197 ft. E. E. Fernandini is driving a new adit 985 ft. above the deep adit, the requisite length of which, to get under the old ore-shoot, will be 3,937 ft. Experimental furnaces have been erected.

There are hot springs near the mine which deposit sinter so abundantly that it serves as a building stone.

Junín.—In the Yauli district of the Department of Junín seams and pockets of cinnabar occur in quartz veins in schists and sandstones. The ore is associated with pyrite. Hot springs, close by, deposit sulphur at the surface.

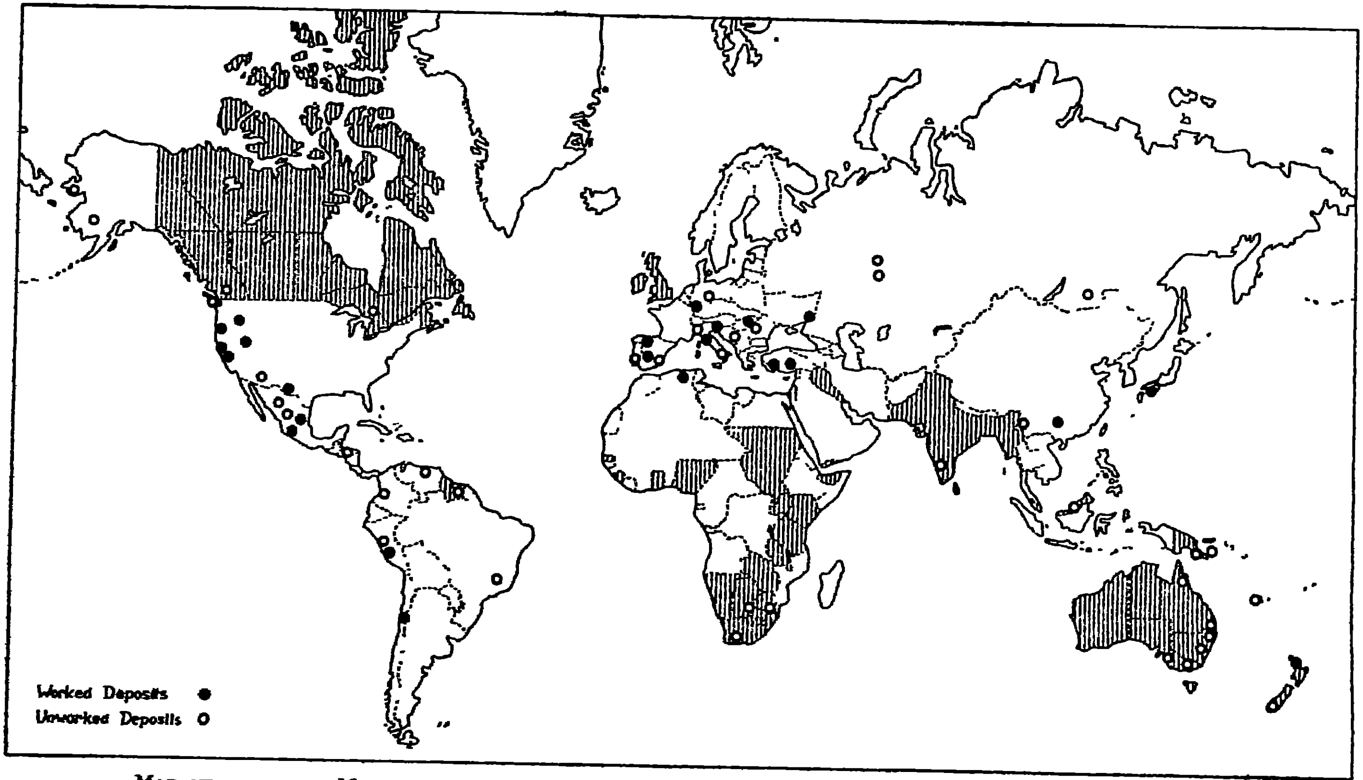
At Ancachs cinnabar is said to be present in veins carrying galena, blende, pyrite and chalcopyrite.

In the silver district of Cerro de Pasco, cinnabar occurs in the neighbourhood of rhyolitic and trachytic lavas [26/p. 471].

Huánuco—In the Chonta district of the Department of Huánuco are three blanket-deposits (*mantos*) consisting of pyrite, blende, galena, cinnabar and tetrahedrite, interstratified in sandstone and quartzite of early Palæozoic age The ore is found in patches and pockets connected by small veins of pyrite, and is said to carry 10% mercury and 300 oz. silver per ton [124/p. 454].

VENEZUELA

As far back as 1904 cinnabar was reported to exist in association with sulphur deposits, which result from still active thermal springs near Chaguaramas, Venezuela. The cinnabar occurs in Tertiary bleached sandstone, and is accompanied by pyrite. Information as to the extent and value of this deposit is not available [134].



Map showing the Mercury-bearing Localities referred to in the Text (British Empire shaded)

REFERENCES TO LITERATURE ON MERCURY

The publications are referred to by numerals in the text.

General

[1] *Encyclopædia Britannica*, 11th Ed. Cambridge, 1910, **18**, p. 155.

[2] Ransome, F. L.: "Quicksilver," *Mineral Resources of the United States, U.S. Geol. Survey*, 1917, 1918, 1919 and 1920.

[3] Spurr, J. E. (Ed.): *Political and Commercial Geology and the World's Mineral Resources*, New York and London, 1920.

[4] Dana, J. D.: *System of Mineralogy*, 6th Ed. (E. S. Dana), London, 1892.

[5] Hill, B. F.: "The Occurrence of the Texas Mercury Minerals," *Am. Journ. Sci.*, 1903, **16**, pp. 251–2; *see* also *Bull.* 4, *Texas Univ. Min. Survey*, Oct. 1902.

[6] Moses, A. J.: "Eglestonite, Terlinguaite and Montroydite, New Mercury Minerals from Terlingua, Texas," *Am. Journ. Sci.*, 1903, **16**, pp. 253–63.

[7] Hillebrand, W. F., and Schaller, W. T.: "The Mercury Minerals from Terlingua, Texas," *Bull.* 405, *U.S. Geol. Survey*, 1909.

[8] Sachs, A.: "Der Kleinit von Terlingua in Texas," *Sitzungsber. K. Akad. Wiss., Berlin*, No. 52, 1905, pp. 1091–4.

[9] Thomas, H. H., and MacAlister, D. A.: *The Geology of Ore Deposits*, London, 1909, pp. 223–30.

[10] Broderick, T. M.: "Some Experiments Bearing on the Secondary Enrichment of Mercury Deposits," *Econ. Geology*, 1916, **11**, pp. 645–51.

[11] Emmons, W. H.: "Exploration of Metalliferous Deposits," *Bull.* 123, *Am. Inst. Min. Eng.*, 1917, p. 364.

[12] Kuss, M. H.: "*Mémoire sur les Mines et Usines d'Almaden*," Paris, 1878; reprinted from *Annales des Mines*, Ser. 7, 1878, **13**.

[13] Molina, Manuel Malo de: *Laboreo de Minas*, 2 vols. and atlas, Cartagena, 1889.

[14] De Kalb, Courtenay "The Almaden Quicksilver Mine," *Econ. Geology*, 1921, **16**, p 308.
[15] *Min Journ.*, Jan 14, 1922, p 24
[16] Orenstein, A J : "Mercurial Poisoning," *Journ. Chem. Met. and Min. Soc., S Africa*, April 1920, pp. 175–6.
[17] Bradley, W. W.: "Quicksilver Resources of California," *Bull* 78, *California State Min Bur.*, 1918.
[18] Gowland, W . *The Metallurgy of the Non-Ferrous Metals*, London, 1918, pp. 406–28.
[19] *Mineral Industry*, New York and London (Annual).
[20] Duschak, L H , and Schuette, C. N. "Fume and Other Losses in Condensing Quicksilver from Furnace Gases," *Tech. Paper* 96, *U.S. Bureau of Mines*, 1919, p. 25.
[21] *Min. and Sci Press*, March 20, 1920, p. 424.
[22] *Eng and Min Journ.*, July 17, 1909, pp. 112–6.
[23] Smith, G O (Ed) · *The Strategy of Minerals*, New York and London, 1919, p. 109
[24] *Journ Inst Metals*, 1912, **7**, pp. 297–8.
[25] *Journ. Inst Metals*, 1919, **22**, pp 346–7.
[26] Beyschlag, Vogt and Krusch (Trustcott) : *The Deposits of the Useful Minerals and Rocks*, London, 1914, **1**, pp. 457–87.
[27] *Min. Journ*, Jan. 7, 1922, p. 13.

British Borneo

[28] De Launay, L.: *Traité de Métallogénie-Gîtes Minéraux et Métallifères*, Paris, 1913, **3**, pp. 404–64.
[29] Posewitz, T. (Hatch): *Borneo: Its Geology and Mineral Resources*. London, 1892, pp. 419–25.

Nyasaland

[30] Foreign Office · *Peace Handbooks of Historical Section, Foreign Office*, London, 1920.

Union of South Africa

[31] Imperial Institute : "The Occurrence, Distribution and Uses of Mercury," *Bull. Imp. Inst.*, 1913, **11**, pp. 479–95.
[32] Johnson, J. P.: *The Mineral Industry of Rhodesia*, London, 1911, pp 42–3.

Canada

[33] Monckton, G. F.: "Cinnabar-bearing Rocks of British Columbia," *Trans. Inst. Min. Eng.*, 1904, **27**, pp. 463–9.

[34] Merritt, W. H. "Occurrence of Cinnabar in British Columbia," *Trans (Fed) Inst Min. Eng.*, 1898, **13**, pp. 592–4.
[35] *Ann. Repts Canada Geol Survey*, 1896, pp 83–5S; 1898, pp 108–9S; 1900, pp 87–9S; 1901, pp 152–3S
[36] Drysdale, C W "Geology of the Thompson River Valley below Kamloops Lake, B C." *Summ Rept., Canada Geol. Survey*, 1912, pp 145 and 155
[37] *Ann. Repts. Min of Mines, British Columbia*, 1900, pp 891–2; 1902, H, pp. 191–2; 1908, J, p. 123, 1918, K, p. 237.
[38] Dolmage, V "Barkley Sound, Vancouver Island, B C.," *Summ Rept., Canada Geol. Survey*, 1919, Pt B, pp 18–20B.
[39] Clevenger, G. H: "Note upon the Occurrence of Mercury in Cobalt Ores," *Econ Geology*, 1915, **10**, pp. 770–3.

AUSTRALIA

[40] Carne, J. E.: "Mercury or 'Quicksilver' in New South Wales, etc.," *Min. Res.* No. 7, *Dept. Mines, New South Wales Geol. Survey*, 2nd Ed., 1913
[41] Rands, W. H: "The Geology and Mineral Resources of the Districts of Kilkivan and Black Snake," *Publ.* 28, *Queensland Geol. Survey*, 1886, p. 8.
[42] Rands, W. H.: "Alluvial Cinnabar Deposits near Kilkivan," *Publ.* 79, *Queensland Geol Survey*, 1892
[43] Ball, L. C.: "Mercury, Copper and Coal Mines, Little River, Cook District, Queensland," *Publ.* 222, *Queensland Geol. Survey*, 1910, p. 21.
[44] Ball, L. C.: "Mercury in Queensland," *Queensland Govt. Min. Journ*, Dec. 15, 1914, pp. 623–9.

NEW ZEALAND

[45] *Ann. Rept. New Zealand Mines Dept., Geol. Survey Branch (New Series)*, 1920, pp. 5 and 12.
[46] Fraser, Colin: "The Geology of the Thames Subdivision, Hauraki, Auckland," *Bull.* 10, *New Zealand Geol. Survey (New Series)*, 1910, pp. 65–6.
[47] Griffiths, André P.: "The Ohaeawai Quicksilver Deposits," *Trans. New Zealand Inst. Min. Eng.*, 1898, **2**, pp. 48–55; also *New Zealand Mines Record*, 1899, **2**, pp. 311–6.
[48] Bell, J. M., and Fraser, C.: "The Geology of the Waihi-Tairua Subdivision, Hauraki Division," *Bull.* 15, *New Zealand Geol. Survey (New Series)*, 1912, pp. 119–21.

[49] Marshall, P "The Geology of the Tuapeka District, Central Otago Division," *Bull.* 19, *New Zealand Geol. Survey (New Series)*, 1918, p 44

[50] *New Zealand Mines Statement*, 1920

GERMANY

[51] Muller, H : "Quecksilberlagerstatten von Hartenstein," *see* Von Cotta's *Gangstudien*, 1857, **3**, pp 170–4.

[52] Beck, R (Weed). *The Nature of Ore Deposits*, New York and London, 1905, **2**, pp 350–60.

HUNGARY

[53] Cotta, B von (*trans. by* A. F Prime, Jr.): *A Treatise on Ore Deposits*, New York, 1870

ITALY

[54] Lipold, M von: *Jahrb. K.K Geol. Reichsanst.*, 1853, pp. 422–869; 1856, p. 838; 1857, pp 205, 385, and 760; 1858, p 18; 1874, p. 425; 1879, p. 186.

[55] Lipold, M. von. *Das K K. Quecksilber-werk zu Idria in Krain*, Vienna, 1881.

[56] Kossmat, F. "Ueber die Geologischen Verhaltnisse des Bergbaugebiltes von Idria," *Jahrb. K.K. Geol Reichsanst.*, 1899, Pt 2, pp. 259–86

[57] Göbl, W. *Geologisch-Bergmännische Karten mit Profilen von Idria nebst Bildern von den Quecksilberlagerstätten in Idria*, Vienna, 1894 (text by A. Plaminek).

[58] Schrauf, A.: "Ueber Metacinnabarit von Idria und dessen Paragenesis," *Jahrb K.K. Geol. Reichsanst.*, 1891, p. 349; also 1892.

[59] Lindgren, W. *Mineral Deposits*, New York and London, 1913.

[60] Rzehak, A.: "Die Zinnoberlagerstätte von Vallalta-Sagron," *Zeitschr. prakt. Geologie*, 1905, pp. 325–30.

[61] Sterner-Rainer, R. (Schuette): "The Present Status of Quicksilver Metallurgy in Europe," *Oesterr. Zeitschr. Berg- u. Hüttenwesen*, 1914, **62**, p. 529; *see Chem. and Met. Eng.*, Dec. 1, 1918, pp. 770–5, and Jan. 15, 1919, pp. 82–4.

[62] De Castro, C.: "Il Minerale di Mercurio del Monte Amiata," *R. Ufficio Geologico, Memorie Descrittive della Carta Geologica d'Italia*, 1914, **16**, pp. 1–209.

[63] De Ferrari, P.: *Il Minerale di Mercurio del Monte Amiata*, Florence, 1890.

[64] Primat: "Note sur les Gîtes de Mercure de Monte Amiata," *Annales des Mines*, Ser 8, 1888, **14**, pp. 95–130.

[65] Spirek, Vicente: "Das Zinnoberzvorkommen am Monte Amiata," *Zeitschr prakt Geologie*, 1897, pp. 369–74; 1902, pp. 297–9

[66] Spirek, Vicente. "Le Gisement de Cinabre de Monte Amiata," *Congr Internat Mines, etc*, 1905; *see* also *Min Mag*, April 1906

[67] Verri, A: "Il Monte Amiata," *Boll. Geol. Ital.*, Rome 1903, **22**, pp 9–39.

[68] *Min. and Sci. Press*, March 20, 1920, p 424.

[69] Petiton, M: "Note sur la Mine de Mercure du Sièle," *Annales des Mines*, Ser 7, 1880, **17**, p 35

[70] D'Achiardi, Antonio: *Minerale di Mercurio in Toscana: Considerazione generale sulla Genesi Loro*, 1877

[71] Rosenlecher, R. "Die Quecksilbergruben Toskanas," *Zeitschr prakt Geologie*, 1894, pp 337–53.

[72] Kloos: "Zinnober fuhrende Trachyttuffe vom Monte Amiata im Südlichen Toskana," *Zeitschr prakt. Geologie*, 1898, pp. 158–63

[73] Lotti, B: "Il Monte Amiata," *Boll. R Com. Geol. Ital.*, 1878, **9**.

RUSSIA

[74] Ernst, C. von. "Das Neue Russische Quecksilberwerk bei Nikitovka," *Oesterr. Zeitschr. Berg- u. Hüttenwesen*, 1889, **37**, p. 430.

[75] Tschernyschew, T., and Loutouguin, L.: *Guide des Excursions du VII^e Congrès Intern. Géologique*, 1897, Paris, pp. 36–45.

[76] Phillips, J A., and Louis, H.: *A Treatise on Ore Deposits*, 2nd Ed., London, 1896, p. 552.

[77] *The Russian Year Book*, London, 1916, p. 234.

[78] *Min. Journ.*, March 2, 1895, p. 243.

SPAIN

[79] Gandolfi, G.: "Les Mines et Usines d'Almaden," *Rev. Univ. Mines*, 1889

[80] Dory, A.: "Le Mercure dans les Asturies," *Rev. Univ. Mines*, 1895, **32**, pp 209–47.

[81] Becker, G. F.: "Geology of the Quicksilver Deposits of the Pacific Slope," *U.S. Geol. Survey Monograph* 13, 1888.

YUGO-SLAVIA

[82] Wray, D. A. "The Geology and Mineral Resources of the Serb-Croat-Slovene State," *Rept. of Geologist attached to British Economic Mission to Serbia, Dept. of Overseas Trade*, 1921.

[83] Fischer, H: "Die Quecksilberlagerstätten am Avala-Berge in Serbien," *Zeitschr. prakt. Geologie*, 1906, pp. 245–56.

[84] Groddeck, A. von: "Ueber das Vorkommen von Quecksilbererzen am Avala-Berge bei Belgrad in Serbien," *Zeitschr. Berg-, Hütten- u. Salinenwesen Preuss. St.*, 1885, **33**, p. 112.

[85] Fuchs, E., and De Launay, L.: *Traité des Gîtes Minéraux et Métallifères*, Paris, 1893, **2**, pp. 672–80.

ASIA MINOR

[86] Monaci, F. P.: *Rassegna Mineraria*, April 11, 1908, p. 138; abs. *Eng. and Min. Journ.*, July 11, 1908, p. 85.

[87] Penzer, N. M.: "The Minerals of Anatolia," *Min. Mag.*, Oct. 1919, pp. 218–9.

[88] Sharpless, F. F. "Mercury Mines at Koniah, Asia Minor," *Eng. and Min. Journ.*, Sept. 26, 1908, pp. 601–3.

[89] Weiss, K. E. "Lagerstatten in Westlichen Anatolien," *Zeitschr. prakt. Geologie*, 1901.

[90] D'Achiardi, G.: "Notizie sul Giacimento Cinabrifero di Karabarun nell Asia Minore," *Soc. Sci. Nat.*, 1903, **13**, pp. 173–6.

CHINA

[91] Brelich, H.: "Chinese Methods of Mining Quicksilver," *Trans. Inst. Min. and Met.*, 1904–5, **14**, pp. 483–95.

PERSIA

[92] Admiralty: "*Handbooks*," *Geog. Sect. Naval Intell. Div., Naval Staff*, 1920.

ALGERIA

[93] De Launay, L.: *Les Richesses Minérales de l'Afrique*, Paris, 1903.

MEXICO

[94] Ramírez, Santiago: "Informe sobre el Mineral de Guadalcázar en el Estado de San Luis Potosí," *An. Minist. Fomento*, 1877, **3**, pp. 395–7.

Rundall, W H.. "Mining and Treatment of Quicksilver Ores at Guadalcázar, Mexico," *Eng. and Min Journ*, June 29, 1895, pp 607–8.

Mactear, J : "Mining and Metallurgy of Quicksilver, Mexico," *Trans Inst. Min and Met*, 1895–6, **4**, p. 69

Merrill, F J H "The Mercury Deposits of Mexico," *Min. World*, 1906, **24**, p 244.

Collins, H F.: "Quicksilver Mining in the District of Guadalcázar, State of San Luis Potosí, Mexico," *Trans. Inst. Min. and Met.*, 1895–6, **4**, p 121.

Capilla, Alberto. "Breves Anataciones sobre la Mina de Mercurio 'La Guadalupana,' San Luis Potosí," *Mem. Soc. Cient. "Antonio Alzate,"* 1904, **13**, pp. 423–7.

Mexican Year Book, London, 1909–10, pp. 482–4

Babb, P. A. "Dulces Nombres Quicksilver Deposit, Mexico," *Eng. and Min. Journ.*, Oct 2, 1909, pp 684–6

Halse, E : "The Quicksilver Mines and Reduction Works at Huitzuco, Guerrero, Mexico," *Trans. (Fed) Inst. Min. Eng.*, 1895–6, **10**, p 72

Pagliucci, F D. "The Quicksilver Deposits of Huitzuco," *Eng. and Min Journ.*, March 2, 1905, pp. 417–8.

Villarello, J. D. "Génesis de los Yacimientos Mercuriales de Palomas y Huitzuco," *Mem. Soc Cient. "Antonio Alzate,"* 1903, **19**, pp. 95–136.

Villarello, J. D.: "Description des Mines 'La Bella Unión' Génèse des Gisements de Mercure," *Mem. Soc. Cient. "Antonio Alzate,"* 1906, **23**, pp. 395–411

Villarello, J. D.. "Descripción de los Criaderos de Mercurio de Chiquilistlán, Jalisco," *Mem Soc Cient. "Antonio Alzate,"* 1904, **29**, pp. 389–97.

UNITED STATES

Smith, P. S.: "The Lake Clark-Central Kuskokwim Region, Alaska," *Bull.* 655, *U.S. Geol. Survey*, 1917, pp. 139–50.

Smith, P. S., and Maddren, A. G.: "Quicksilver Deposits of the Kuskokwim Region," *Bull.* 622, *U.S. Geol Survey*, 1915, pp. 272–91.

Brooks, Alfred H., and others: "Mineral Resources of Alaska," *Bull.* 592, *U.S. Geol. Survey*, 1914, p. 37.

Ransome, F. L.: "Quicksilver Deposits of the Mazatzal Range, Arizona," *Bull.* 620, *U.S. Geol. Survey*, 1915, pp. 111–28.

[111] Schrader, F. C.: "Quicksilver Deposits of the Phœnix Mountains, Arizona," *Bull.* 690, *U.S. Geol Survey*, 1918, pp. 95–109

[112] Forstner, W.: "Quicksilver Resources of California," *Bull* 27, *California State Min Bur.*, 1903.

[113] Coignet, M *Rapport sur les Mines de New-Almaden*, Paris, 1866

[114] Larsen, E S., and Livingston, D C: "Geology of the Yellow Pine Cinnabar-Mining District, Idaho," *Bull.* 715E, *U S Geol. Survey*, 1920.

[115] Knopf, A.: "Some Cinnabar Deposits in Western Nevada," *Bull.* 620D, *U.S. Geol Survey*, 1915

[116] *Min and Sci. Press*, March 27, 1920, p. 465

[117] Kellog, A E.: "Quicksilver in Southern Oregon," *Min. and Sci. Press*, March 25, 1922, pp. 411–3.

[118] Udden, J A "The Anticlinal Theory as Applied to Some Quicksilver Deposits," *Texas Univ. Bur of Econ Geology and Technol*, No. 1822, April 18, 1918.

[119] Emmons, W. H *General Economic Geology, A Textbook*, New York and London, 1922, pp 482–4

[120] Turner, H W. "The Terlingua Quicksilver Deposits," *Econ. Geology*, 1906, **1**, pp. 265–81.

[121] Philips, W B. "The Quicksilver Deposits of Brewster County, Texas," *Econ. Geology*, 1906, **1**.

[122] Boutwell, J. M "Quicksilver," *Mineral Resources of the United States, U.S. Geol Survey*, 1906, p. 494.

[123] Ransome, F. L.: "Our Mineral Supplies," *Bull.* 666, *U.S. Geol. Survey*, 1919, p. 211.

BRAZIL

[124] Miller, B. L., and Singewald, J. T.: *The Mineral Deposits of South America*, New York and London, 1919.

CHILE

[125] *Min. and Sci. Press*, July 1, 1916.

[126] Götting, A.: "Die Erzgänge zu Punitaqui in Chile, mit besonderes Beruchtsichtigung der Zinnoberführenden Lagerstätten," *Zeitschr. prakt. Geologie*, 1894, pp. 224–30.

[127] Domeyko, I.: "Sur les Mines d'Amalgame Natif d'Argent d'Aqueros au Chile," *Annales des Mines*, 1841, **20**, pp. 255–307.

COLOMBIA

[128] Gamba, F. P.: "Minas de Cinabrio del Distrito de Bermel-lón," *Riqueza Mineral de la República de Colombia*, Bogotá, 1901, pp. 194–7.

[129] Halse, E.: "Note on the Occurrence of Mercury at Quindiú, Tolima, U.S. Colombia," *Trans. (Fed.) Inst. Min. Eng.*, 1893–4, **6**, p. 59.

PERU

[130] De Rivero, M. M.: *Memoria sobre el Rico Mineral de Azogue de Huancavelica*, Lima, 1848.

[131] Singewald, J. T.: "The Huancavelica Mercury Deposit, Peru," *Eng. and Min. Journ.*, Sept. 11, 1920, p. 518.

[132] Strauss, L. W.: "Quicksilver at Huancavelica, Peru," *Min. and Sci. Press*, Oct. 23, 1909.

[133] Umlauff, A. F.: "El Cinabrio de Huancavelica," *Bol. 7, Cuerpo. de Ing. de Minas del Perú*, 1904.

VENEZUELA

[134] *Eng. and Min. Journ.*, Nov. 10, 1904, p. 741.

ADDENDA

[135] Black, T. A.: "Mercury in New Zealand," *Chem. Eng. and Min. Rev.*, Oct. 5, 1922, p. 17.

[136] Ransome, F. L.: "Quicksilver in 1921," *Mineral Resources of the United States, U.S. Geol. Survey*, 1921, pp. 116–7.

[137] Fermor, L. L.: "General Report of the Geological Survey for the year 1921," *Rec. Geol. Survey, India*, 1922, **54**, pt. 1, p. 26.